The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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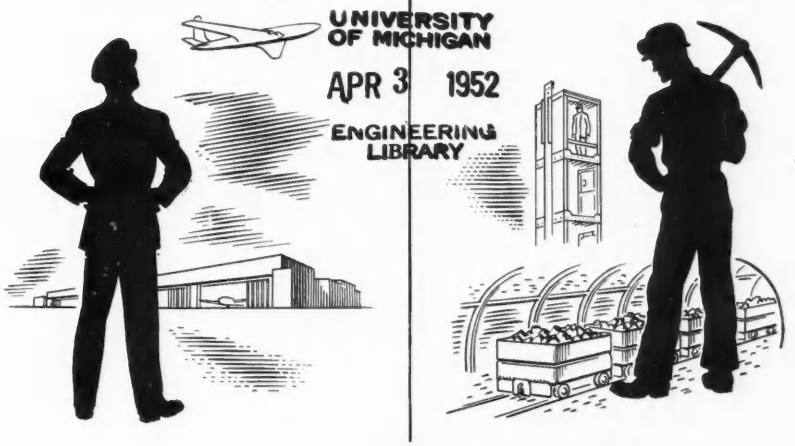

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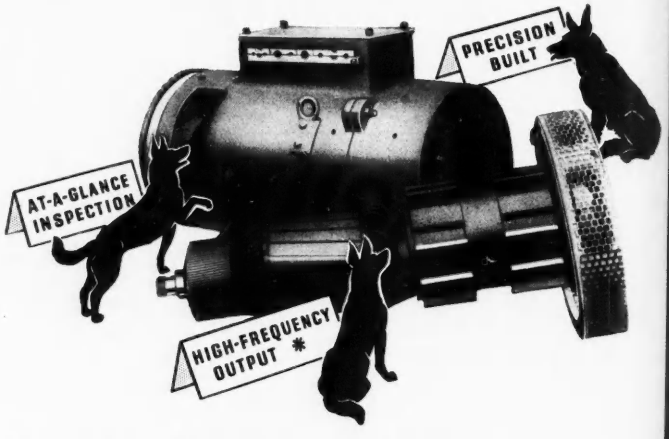

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *DETINNING PLANT*

For the first time a steel company has installed its own detinning plant in order to conserve its stock of tin and also to recover scrap which formerly could not be used in open-hearth furnace operation because of the contaminating action of the tin coating. After cutting open the bales, the scrap is dropped by a magnet crane into the charging hopper, whence the scrap is fed into the detinning drums. These are cylindrical steel drums of 8 ft. diameter and 11 ft. length with one fixed end and one removable end plate. The cylindrical portion of the drum consists of a frame supporting a heavy wire mesh screen. A scrap charge averaging from 5,400 to 6,000 lb is discharged from the hopper into the drum, while it is standing upright. After charging, the removable end plate is bolted in place and the drum is brought into the horizontal position and lowered into the detinning tank. The detinning reagent is a 50 per cent solution of sodium hydroxide with an addition of sodium nitrate. A closed coil system heats the solution to 195° F. Sodium stannate is precipitated out of saturated solution in the form of a slurry. The latter is passed into a filter and precipitation tanks, in which the sodium stannate is slightly acidified with sulphuric acid and the tin hydroxide precipitated by adding sodium carbonate. Following the detinning process, which requires 2½ hours to complete, the drum is removed from the detinning tank and plunged into two rinse tanks. After the processed scrap has been cleaned, it is discharged from the drum onto a table, from which it is fed into a hydraulic scrap baler.

● *PLASTICS FOR PIPING*

With the coming of the plastic age, it was inevitable that plastics should also be used for piping, and present-day trends are towards a rapid expansion in the employment of plastic materials for piping of various kinds. The most basic, but not necessarily the simplest, application of plastics to pipe is in the form of coatings, and as a result of the development of synthetic rubber manufacture, co-polymers of butadiene, acrylonitrile and styrene acrylonitrile have come into use for internal coatings. Of an entirely different type, and highly effective where best resistance to corrosion is required, but where cost and difficulty of application are not decisive, is tetrafluoroethylene applied as a spray. Baked phenolformaldehyde resins are, of course, also widely applied for internal coatings. Both plastic coatings and plastic pipe should prove extremely useful in coal mining practice, where the life of steel pipe is often extremely short. One of the most recent and most promising materials for pipe lining are claimed to be the vinyl-vinylidene polymers which are moulded or extruded to slightly less than the inside diameter of the pipe they are to fit and then mandrel-fitted into it. Extruded cellulose acetate butyrate tubing is also claimed to be highly suitable for lining steel pipe. This material is placed in the steel pipe and then blown to size by means of steam. For coal mining service, flexible polyethylene pipe is claimed to be eminently applicable, and this type of pipe has also given excellent service in non-industrial and particularly agricultural service. Among most recent developments, a valve of polythylene with packing rings of polyethylene-polyisobutylene mixture may be mentioned. These valves are resistant to inorganic acids at temperatures up to 170° F.

● *ELECTRIC MOTOR OF NEW DESIGN*

In a most interesting novel electric induction motor, both armature and stator are entirely different from any conventional design, and even the field produced by the stator coils is modified. Briefly, the armature, of laminated construction, is made in the shape of a circular swash plate which rolls along the periphery of the tapered stator surface, so that a rotating single line of radial contact is produced. For this purpose, the stator surface is covered with rubber or other suitable material. As the stator has two concentric annular pole-pieces, the line contact made by the swash plate closes the magnetic circuit between the stator rings. The stator is furnished with a three-phase winding as well as a direct current winding, the latter suppressing one half of the revolving alternating field so that a revolving field of constant polarity obtains. This field is not, of course, uniform in strength, but varies in magnitude from zero to its maximum as a result of the superimposition of the d.c. field over the a.c. field. In the d.c. field coil, the pulsating field induces an alternating electromotive force of six times the frequency of the a.c. power supply; this is eliminated by chokes. A two-pole machine of this type has a maximum speed of 500 rpm at 50 cycles, but the actual speed depends upon the relative angle made by the contact line of the

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swash plate with the stator. So far, machines for 150 rpm have been developed. The advantage offered by this new motor type is its low specific speed, which results in a much lower armature inertia than can be obtained with motors of conventional design. It should therefore prove particularly suitable in applications where quick starting and stopping are required.

● *SIMPLIFYING CASTINGS BY SANDWICH CONSTRUCTION*

A new method of making aluminium cylinder heads, cylinder blocks, and similar products difficult to produce economically by conventional casting methods, has been developed in the U.S.A. In the new process, cast component parts are stacked one upon the other and then brazed together to form a sandwich-like product of the required shape. This unorthodox method of joining cast aluminium component parts together makes it possible to produce a variety of parts which formerly called for intricate sand cores in fabrication, but which now can be produced by a combination permanent mould-furnace brazing process. Thus, for instance, cylinder heads can be cast by the permanent mould process in two or more integral sections, with the sections or slices being furnace-brazed together for final assembly. The standard design of an ordinary cylinder head must be altered slightly to permit the individual sectional casting of each slice. The permanent mould casting process, which is well-suited to mass production techniques, eliminates the necessity of cores normally employed during the production of a one-piece, semi-permanent-mould or sand cast product. A most important consideration in this process is the selection of the filler material to be used for joining the component parts by brazing. According to the original report, extensive experiments showed that a suitable brazing material in thin sheet form stamped to the outline of the exposed joining surfaces would be ideal for most automotive applications of the process. The thickness of the brazing gaskets is dependent on the size of the unit involved and the strength required in the joint.

● *HARD METAL ALLOY WITH HIGH HEAT CONDUCTIVITY*

A recent invention proposes to increase the rather low heat conductivity of sintered tungsten carbide—titanium carbide—cobalt tools in order to improve their grinding and machining properties. To this end, it is proposed to add 0·5 to 3 per cent copper or beryllium, which have a high heat conductivity, to the aforementioned alloy. This suggestion is based on the discovery that not all metals of high heat conductivity are suited to be added to a tungsten carbide—titanium carbide —cobalt alloy. The inventors claim to have ascertained that only those metals of high heat conductivity which do not form an alloy with the carbides present render the desired effect. It has been found that one of the most suitable materials for this purpose is copper. This metal has a heat conductivity almost ten times that of steel and almost twenty times that of tungsten carbide-titanium carbide-cobalt alloy containing 25 per cent titanium carbide and 6 per cent cobalt. At the sintering temperature of this hard metal, copper is in its liquid phase without, however, mixing with the carbides ; it thus fulfils the aforementioned condition. Similar beneficial effects can be secured by the addition of beryllium. In order to obtain the required effect, the addition of a comparatively small proportion of copper or beryllium is sufficient. An addition of 0·5 to 3 per cent increases the heat conductivity of the tungsten carbide—titanium carbide—cobalt alloy to a substantial degree, whilst the high hardness and strength of cutting tools made of the alloy are only slightly decreased. It is claimed that no deterioration in the cutting characteristics of the tools made of the new alloy is noticeable.

● *SCALE REMOVAL BY INDUCTION HEAT*

The removal of surface scale from metal parts after heat treatment has always presented a problem to manufacturing. In most cases, the solution consists in the application of sand blasting or shot blasting or, in the case of small component parts, in the use of tumbling mills. An interesting new method which is claimed to show considerable promise is the application of induction heating to the surface to be descaled. The underlying principle of removing scale by induction heat is to raise the temperature of the surface scale with such rapidity that its consequent expansion will cause it to flake off from the cooler base metal. The progressive heating of the surface scale and the irregular electrical conditions prevailing in the scale cause the latter to disintegrate into small fragments as it separates from the base metal. The use of induction heat presents something of a problem insofar as the scale is magnetically attracted to the induction coil, where it will build up and finally flow off like water. It was, however, found possible to insulate the induction coil electrically and prevent short-circuiting by the scale by applying a coating of high-temperature refractory cement. Quite unexpectedly, the presence of moisture was found to favour the removal of scale by this method. This feature was discovered when descaling bars which had previously been subjected to a water spray quench and had retained some surface moisture. In this case, descaling was found to be more complete than in the case of dry surfaces, owing to the sudden generation of steam, the expansion of which serves to disengage the scale in an explosion-like manner. It is reported that the electric power consumption of the process is sufficiently low to make it an economically attractive proposition.

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● *ELECTROFORMING OF ALUMINIUM COMPONENTS*

Only a few years ago, it was not possible to produce electrodeposited aluminium coatings exceeding 0·05 mm in thickness, since thicker deposits became powdery and spongy. Recent developments in electroplating technique have now advanced to a point where thick electrodeposits of aluminium with improved physical properties can be obtained by a method which its inventors believe to have opened the door for the commercial application of electrodeposited aluminium. The new process was first applied to the manufacture of light-weight wave guides with twists, bends and tapers for radar installations. In this case, a wall thickness of at least 0·5 mm was required for rigidity and strength of the product. In the new process, these wave guides are electroformed by electro-depositing aluminium on electropolished, copper-plated, cadmium-nickel alloy mandrels, followed by melting out the cadmium-nickel alloy and dissolving out the copper in nitric acid solution. This procedure results in the production of mirror-like surfaces on the inner walls of the piece. The aluminium walls of 0·65 to 1·0 mm thickness are dense, strong and ductile, and have a hardness as high as 138 Knoop. The plating bath consists of a dispersion of toluene in a toluene solution of the fusion product of ethyl pyridinium bromide and aluminium chloride with methyl t-butyl ether or another addition agent for improving the physical properties of the aluminium electrodeposit.

● *NOVEL IMPULSE TYPE HEATER*

Impulse type heaters may be used for the preheating of aircraft engines or in cold climates for de-icing the wings before flight and similar purposes. In this type of heater, a charge of fuel and air is drawn periodically into a combustion chamber through a non-return valve, which is the only moving part of the heater, and immediately fired due to the high temperature of the chamber. The burnt gases are discharged at high velocity into a flame tube. The pressure generated by combustion of the charge closes the non-return valve, which subsequently quickly re-opens to draw a further charge into the combustion chamber due to the pressure depression caused by the expulsion of the burnt gases at high velocity. The number of combustion cycles taking place may be as large as 4,000 per minute. In the usual type of impulse air heater, the mixture of hot gases and air produced is toxic because it contains a percentage of carbon monoxide derived from the combustion chamber. This imposes limitations on the range of applications of this heater type. In a new type covered by a recent patent, an air tube surrounds the combustion chamber and flame tube, and a gas turbine-driven fan is mounted in the air tube. This turbine is driven by the gases rejected from the flame tube, and its fan forces a stream of uncontaminated air over the combustion chamber and the flame tube, while the exhaust gases are rejected to the exterior of the air tube. This heater therefore supplies a stream of heated fresh air which, for instance, may be used for the preheating of aircraft cabins, etc.

● *HYDRODYNAMIC INVESTIGATION OF BESSEMER CONVERTERS*

Owing to the intense heat and flame and spark formation obtaining in the operation of the basic Bessemer converter, observation of the agitation of the metal bath in the converter is difficult. In order to study the state of agitation prevailing in the vessel, with a view to reducing the violence of the stirring process without lowering its efficiency, it was decided to resort to the use of models. These models were built to the scale of 1:10 and 1:7·5 respectively, and water was used instead of the liquid metal. By passing an air stream through the tuyeres of the models, a good insight could be obtained into the type of agitation produced, and the maximum permissible air supply rate could be determined. In order to take into consideration the different fluid properties of water and liquid metal, blowing experiments were also made with a number of liquids other than water. The list included the use of alcohol, acetic acid, glycerine, oils, and a lead-cadmium-bismuth-tin alloy in liquid state at 70° C, having a density in excess of that of steel. These tests clearly showed the influence of viscosity upon the state of agitation of the bath. Two design factors were found to exert a fundamental influence upon the agitation of the bath, namely, the position of the air inlet tuyeres at the bottom of the converter and the actual shape of the converter. In order to ascertain the accuracy of the findings and their applicability to actual converters, a number of comparative tests on actual converters was subsequently carried out, the results of which were in satisfactory agreement with those obtained on the models.

● *NYLON AS BEARING MATERIAL*

The outstanding mechanical properties of nylon have led to its use in many applications remote from those for which it was originally intended. The latest of such uses appears to be that as a bearing lining in cases where needle bearings are normally employed. It is well known that needle bearings are particularly useful where high oscillating loads are to be carried, and it need hardly be explained that the particular characteristics of nylon make it a suitable substitute material for this purpose. The new bearing was developed for a specific ordnance application and contains a nylon-fabric suspension consisting of two nylon rings absorbing the highly oscillating stresses imposed upon the bearing. The rings are placed on either side of the self-lubricating fabric material,

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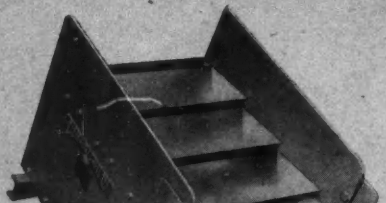

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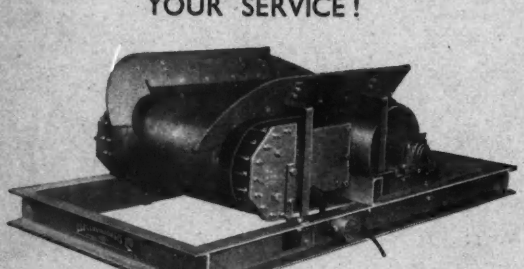

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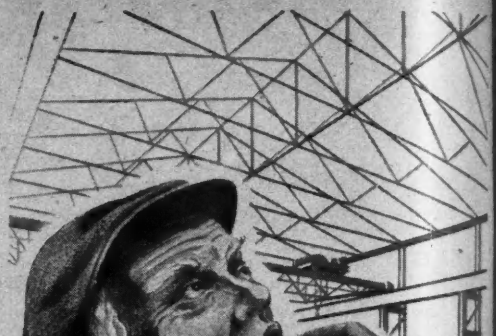

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and the stress distribution is controlled by the dimensions of the nylon rings relative to the fabric bearing. In service, the bearings are subjected to high unit stresses during impact conditions. Usually, the oscillating motion is quite small because of the high spring rates and overload reserve capacity of the springs. These conditions facilitated the design of the nylon fabric bearing insofar as they permitted the provision of a more effective bearing area under given conditions. The new bearing is designed to proportion the load between the two types of materials, the fabric carrying the normal load and the nylon rings supporting the impact load. Considering present-day shortages in manpower and material in the ball-bearing industries, there should be a considerable number of possible applications for these novel bearings.

● *NOVEL VISCOMETER*

A novel type of viscometer for measuring the viscosity of liquids has become available which is capable of giving practically instantaneous indication. Its range is claimed to be unusually wide, including acetone and alcohol at the one end of the scale and cup grease and petrolatum at the other. In this instrument, the viscous damping exerted by a liquid on an oscillating flat plate is measured by an electromechanical transducer. The vibrating plate is made of stainless steel 0·01 in. thick and 0·2 in. in diameter. By means of a clamping block, the plate is mounted on the free end of a flat steel reed of 0·875 in. length which is rigidly clamped at the opposite end. This reed is set into vibration by an electromagnetic driving system and causes the plate to carry out linear oscillations in its own plane. A ceramic barium-titanate block is mounted on each side of the steel reed. Flexing of the barium titanate caused by the motion of the reed generates a piezoelectric voltage at electrodes on the surface of the barium titanate, and this voltage is proportional to the amplitude of vibration. In order to obtain reliable and consistent results, it was found necessary to use a vibration frequency of 800 cycles per second. By using a number of liquids of known viscosity, the instrument is calibrated so that the viscosity can be read off the dial of the viscometer. Accuracy of the instrument is claimed to be within 5 per cent. Liquid samples as small as 0·5 cm^3 may be investigated. The instrument may be used for continuous indication or registration.

● *CONTROL OF HOT MACHINING*

In hot machining, the material to be removed is heated to a temperature at which the shear strength of the metal is considerably reduced, so that cutting can proceed with great facility. The temperature required varies with different metals; also, as the tool becomes more dull in service, more heat must be applied to maintain output. Even if it were possible to measure the temperature of the heated metal with sufficient accuracy by means of a thermometric device, such a temperature indication would not consistently and accurately reflect the shear resistance offered by the metal to the tool, owing to the influence of such variable factors as tool condition, depth of heating and the like. It has, however, been found that the degree of reduction in shear resistance in the material is accurately reflected in the strain set up by the cutting tool. This fact can be exploited for the control of the heating effect by measuring the strain produced by the cutting action, a strain measuring gauge being used for this purpose. Such a strain-responsive device may be applied to the tool or the tool holder, or to the bed of the machine, or to the workpiece, and either electrical or hydraulic types, or in fact any suitable type, of strain gauge may be used. The application of heat to the workpiece will generally be by means of high-frequency induction heating. Alternatively heat may be applied by the use of one or more torches. The strain gauge type of control lends itself equally well to either type of heating, and in a given case it is merely a question of selecting the appropriate control mechanism.

● *IMPROVED DRY BATTERY*

Manganese dioxide is the most important single constituent of a dry battery from the aspects of service life and capacity. The quality of the manganese dioxide used in the manufacture of a battery, therefore, is vital in cases where batteries are employed for military uses, or where they are held in readiness for emergency use in civilian applications. As the supply of manganese dioxide of the quality required is largely confined to a single source in Africa, it was considered important by the U.S. Army Signal Corps to find a way of utilising low-grade manganese dioxide of American origin instead. It is reported that a way has been found to convert this low-grade material into a product of a quality so high that it is almost twice as effective in dry batteries as the best material used hitherto. As the result of extensive investigations and research, a pilot plant process was developed for the production of a high-quality, battery-grade manganese dioxide, and it is claimed that the batteries made with this material have proved to be capable of developing about twice the amount of power delivered by existing battery types. Manufacture of the new batteries has now been placed on a mass production basis, and it will be interesting to have the results of an independent test of the new battery type if and when the batteries become available on the market. Independent substantiation of the claims made for the superiority of the new battery should prove particularly timely and valuable in view of the still expanding large-scale use of dry batteries in portable radio receivers, hearing aids, electric torches, and other portable electrical apparatus.

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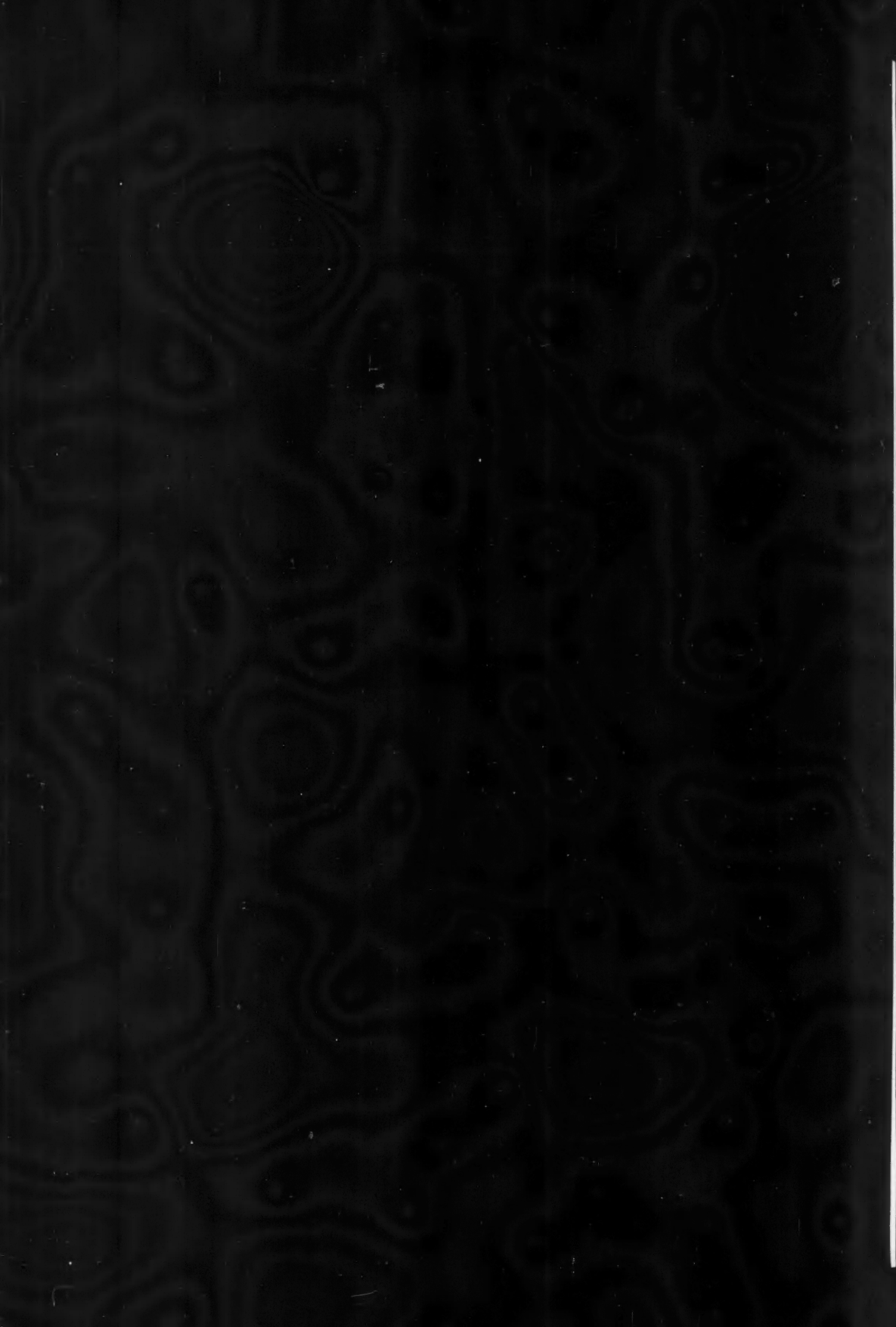

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The Geography of Steel

In the year just ended (1951) the world production of steel is estimated to have exceeded 200 million tons. In the U.S. alone, the steel industry provides a livelihood for nearly one million people. and during 1951 turned out a record production of some 106 million tons. And there is every prospect that this figure will be exceeded by a handsome margin before the decade is out.

George H. T. Kimble, Director of the American Geographical Society, has given, in a recent issue of *Scientific American*, a general account of the supply position of the raw materials required for the production of steel. Although his account is concerned mainly with the supply position as it affects the American economy, we thought that, in view of the great steel shortage in this country and the heavy demands for steel to carry out the European defence programme, readers would be interested to know how America, despite her enormous resources at home, is looking ahead to the future and developing iron ore mining not only in neighbouring South American countries but also on the African continent.

The demand for the things made of steel is insatiable. It has been calculated, for instance, that the average American home has between two and three tons of steel equipment. If every other country follows suit and comes to regard refrigerators, washing machines and automobiles as part of the necessary paraphernalia of 20th-century life, the world output may well rise to a round thousand million tons a year before levelling off—always supposing, that is, that the supply of raw materials does not run out beforehand.

To produce 100 million tons of steel, approximately 135 million tons of iron ore are required, as well as 110 million tons of coal, more than 50 million tons of scrap, more than 30 million tons of limestone, 1·7 million tons of manganese ore, 650,000 tons of chrome ore, 42,000 tons of metallic nickel, 60 million barrels of fuel oil and 275,000 million cubic feet of gas—not to mention 500 million tons of hot air and more than 7,000 million tons of water.

Fuels in the U.S.A. present little or no problem. The critical materials are iron ore and ferro-alloys. Practically all the iron ore comes from three main locations : (1) the Lake Superior field, which still contributes almost four-fifths of the ore used in the U.S., (2) the Alabama field, contributing about eight per cent, and (3) the North-Eastern field, notably the Adirondack region, yielding about four and a half per cent. The rest is made up of shipments from widely scattered states.

The greatest single producing region continues to be the Mesabi range in North-Eastern Minnesota. In 1948, nearly two-thirds of the total U.S. shipments of 101 million tons of ore came from this region. Just how much longer the Mesabi Range and its neighbouring regions can go on disgorging such riches is a question that is much easier to ask than to answer.

The answers of geologists and mining men vary with the assumptions made as to the probable total reserves and the tonnages needed annually. There is, however, a growing body of belief that at existing rates of removal, the high-grade Mesabi ores will be exhausted in a matter of years. This does not mean to say that the Lake Superior region would then be abandoned. In addition to the high-grade hematites, there are vast reserves of lower-grade hematite and taconite in the region. The aggregate iron content of these ores is almost certainly greater than the total shipments of high-grade hematite to date, but their thin concentration poses some weighty metallurgical problems. One reduction plant, however, has already begun to produce pig iron from taconite on a substantial scale. Beginning with an output of 300,000 tons in 1951, it expects to reach five million tons a year by 1955. And plans for a second plant are well advanced.

The Alabama field, it is estimated, can continue to yield good-grade hematites at the existing rates for many years to come. There are other localities in the same Appalachian system, where sizable ore deposits of similar grade (but different chemical constitution) can be drawn upon to boost output. In addition, many fields that had been abandoned are now being cajoled into producing more than ever before, to meet the compelling needs of the American defence mobilisation programme. But the truth of the matter is that none of these fields is a Mesabi.

North of the 49th Parallel, the prospects are brighter. Indeed, there are two very promising deposits right on Mesabi's doorstep. The open-pit Steep Rock mines located 140 miles west of Port Arthur and the Helen Mine near Michipicoten at the north-eastern extremity of Lake Superior are already producing about three million tons a year between them and could comfortably produce

ten times as much, according to the latest reports coming from the Dominion.

Of scarcely less promise is the Labrador-Northern Quebec region. Burnt Creek is known to have at least 400 million tons of hematite analysing at approximately 65 per cent iron. Another deposit situated at Leaf Lake may prove to be even larger.

Ore prospecting in Northern Canada has barely begun. Few parts of the world present the mining company with greater problems—physical or economic. Northern Canada is forbidding country. For eight months in the year it is covered with snow; it is chilly the other four. All food will have to be brought in from outside, either by aeroplane or by a combination of sea, rail and road transport. Living expenses will therefore be very high. Power likewise promises to be expensive. It is difficult to see how labour can be attracted to so desolate a region. Furthermore, the bulk of the labour force must be migratory, since the open season for mining in Northern Quebec promises to be considerably less than six months long.

As long ago as 1915, the Bethlehem Steel Company was mining iron ore in Chile. More recently, it has started to develop another source in Cuba. At the moment, however, the greatest interest is concentrated on the iron ranges flanking the southern banks of the Orinoco River in Venezuela. At the end of a nine-year construction job, which included the building of roads, railways, freights and two brand-new ports, ore shipments are now being made regularly to the Bethlehem Steel works at Sparrows Point, Md., 2,300 miles away. The present rate, 125,000 tons a month, is expected to be stepped up sharply in the course of a year or so.

Meanwhile, the United States Steel Corporation has even more ambitious plans for the development of a deposit at Cerro Bolivar, 80 miles upstream from El Pao. So far, exploration of this range has revealed more than 500 million tons of high-grade ore, and it promises a great deal more. In fact, some geologists are already claiming Cerro Bolivar as the biggest single deposit in the continent, if not in the world. Once U.S. Steel has settled the development terms and royalty rates with the Venezuelan Government, it will not be long before the first shiploads of ore start moving northward towards the Fairless Steel plant now going up along the shore of the Delaware River, 15 miles north-east of Philadelphia. By 1960, annual shipments of Venezuelan ore to this site are expected to exceed 25 million tons.

The search for iron is not limited to Venezuela; it is being diligently pursued in other South American Republics, notably in Brazil, vast areas of which contain most promising iron-bearing formations.

These rich tropical finds are not without drawbacks. Admittedly, it is no more expensive to ship ore from El Pao to Sparrows Point than it is from the Mesabi to Pittsburgh, for transport by ocean-going ship is approximately 10 times as cheap as it is by rail. The chief problem is the same as that in Northern Quebec—climate.

Where else may America look for supplementary supplies of iron ore? The main producing fields of France, Luxembourg, Sweden, Great Britain and Spain, though together capable ot impressive production figures, have their work cuf out at the present time to meet the demands put upon them by civil and military contractors. As it is, Great Britain has to import between six and seven million tons of ore to maintain an annual steel production of roughly 16 million tons. For very different reasons, the massive deposits of the U.S.S.R., said by many competent geologists to be of the same order of magnitude as those of the U.S., lie outside America's present reckoning. So, too, do the deposits of India, whose per capita consumption of steel (12 pounds) is one of the world's lowest. Nor is any other country in free Asia likely to be able to feed American blast furnaces in the foreseeable future. Significant deposits of high-grade ore are scarce in that part of the world. Indonesia, Malaya and the Philippines appear to be better off than their neighbours, but so far none has turned up a Burnt Creek or a Cerro Bolivar. Australia has two major fields, but these barely take care of the rapidly growing domestic market.

We are left, then, with Africa—a continent whose iron-bearing possibilities are only now coming fully to light. It is true that the iron-ore deposits of Barbary States have been worked for many years, mainly for export to Great Britain, and it is equally true that the end of their accessible supplies is not yet in sight. However, it is Africa south of the Sahara that is now attracting most attention. In tropical Africa, the latest estimates of iron-ore potential are equalled only by the optimism that they have inspired. Piecing together the still far from complete reports, it is clear that in four small areas alone there is enough good-quality ore not only to take care of all conceivable needs of Africa for generations to come, but also to provide a handsome export surplus.

These areas are located near Lusaka in Northern Rhodesia, near Que Que in Southern Rhodesia, in the Bomi Hills of Liberia and in the Elgon-Tororo district of Kenya. The most significant of these from the U.S. standpoint is the Liberian field. The Bomi Hills ore, with an iron content averaging almost 70 per cent (compared with 50 to 55 per cent for Mesabi ore) is said to be second to none in the world of quality. To ship the ore to the East Coast ports of the U.S., the Liberia Mining Company has built a fleet of four carriers, each capable of hauling 22,000 tons of ore and

(*Concluded on page* 96)

The Regenerator with a Moving Storage Mass

By H. GLASER. (From *Forschung auf dem Gebiet des Ingenieurwesens*, Vol. 17, No. 1, 1951, pp. 9-15, 9 illustrations.)

Heat exchangers between two gases often make use of the principle of regeneration. In such heat exchangers, a solid mass is heated by the hot gas and subsequently transfers its heat to the cold gas. Hitherto, most generators were operated in intermittent flow, but recently regenerators with a moving storage mass have been introduced. The Ljungström regenerator has a storage mass which rotates across the two streams of hot and cold gas. A new principle of longitudinal flow of storage mass is embodied in the "pebble heater" developed by Babcock and Wilcox. The present author illustrates a heat exchanger of this type, examines mathematically the temperature distribution in it, analyses its calorific efficiency, and compares the storage mass of the new and old regenerator systems. The author concludes that a regenerator, in which storage mass moves against the gas stream, combines in all respects the advantages of regenerators and contra-flow recuperators.

DESCRIPTION.

Fig. 1 shows a longitudinal section through the pebble heater. Two cylindrical chambers *a* and *b* contain the storage mass consisting of balls of $\frac{1}{2}$ in. diameter or less made of refractory material. Storage mass is continuously withdrawn from the lower chamber by means of a mechanical device which permits flow adjustment. The storage mass withdrawn from the apparatus is returned by means of a continuous hauling device to the upper chamber, thus keeping the quantity of storage mass in the regenerator constant. The circuit is completed through the gradual flow of storage mass along the upper chamber and through a neck between the two chambers.

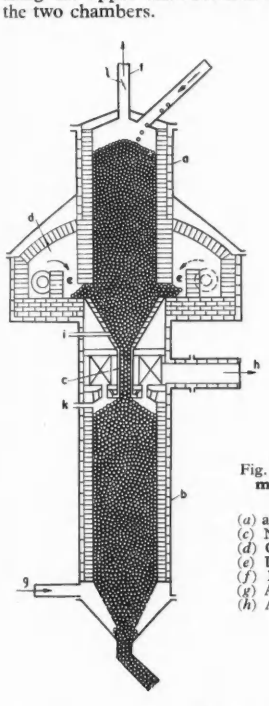

Fig. 1. **Regenerator with moving storage mass (pebble heater).**
(*a*) and (*b*) Chamber walls
(*c*) Neck
(*d*) Combustion chamber
(*e*) Inlet openings for hot gas
(*f*) Flue
(*g*) Air inlet
(*h*) Air outlet

Just above the neck there is an annular combustion chamber *d*, in which a gas of low calorific value is burnt. The hot combustion products penetrate through the openings *e* into the upper chamber *a*, in which they rise to the flue *f*, having transferred on the way most of their heat to the storage mass. The cold air enters the regenerator at *g* and leaves it at *h*, having traversed the length of the lower chamber and picked up most of the heat brought down by the movement of the storage mass. Equality of pressures in the two chambers prevents leakage between the two gas circuits.

TEMPERATURE DISTRIBUTION ALONG THE REGENERATOR.

The author assumes that material constants are independent of temperature and examines the steady state of operation. Heat conduction through the storage mass is neglected.

In the following equations, subscript 1 denotes the region in which storage mass is heated. A regenerator element of the length dx_1 receives during the time element dz a heat element dq.

$$dq = \alpha_1 F_1 \, dx_1 \, (\vartheta_1 - t_1) \, dz \qquad .. \qquad (1)$$

where α_1 [kcal/m² hr °C] is the heat transfer coefficient between gas and storage mass, F_1 [m²/m] is the surface of the storage mass per unit of length of the regenerator, ϑ_1 [°C] is the gas temperature and t_1 [°C] the temperature of the storage mass. The gas flow per unit of time is G_1 [kg/hr] and, hence, a gas quantity $G_1 dz$ flows through the regenerator element and is cooled by the temperature increment $d\vartheta_1$. The heat element dq can also be expressed by

$$dq = - G_1 \, c_{p1} \, dz \, d\vartheta_1 \qquad .. \qquad (2)$$

where c_{p1} [kcal/kg °C] is the specific heat of the gas. The rate of flow of storage mass through the regenerator elements is G_s and the mass $G_s dz$ is heated by the temperature increment dt_1. Hence

$$dq = - G_s \, c_s \, dz \, dt_1 \qquad .. \qquad .. \qquad (3)$$

where c_s is the specific heat of the storage mass. Eqs. (1), (2) and (3) lead to

$$\frac{d\vartheta_1}{dx_1} = \frac{\alpha_1 F_1}{G_1 c_{p1}} (t_1 - \vartheta_1) \qquad .. \qquad (4)$$

and

$$\frac{dt_1}{dx_1} = \frac{\alpha_1 F_1}{G_s c_s} (t_1 - \vartheta_1) \qquad .. \qquad (5)$$

The author defines a dimensionless length parameter

$$\xi_1 = \frac{\alpha_1 F_1}{G_1 c_{p1}} x_1 \qquad .. \qquad .. \qquad (6)$$

A second dimensionless parameter K_1 is, in physical terms, the ratio of the heat capacity flows of gas and storage mass and is defined by

$$K_1 = \frac{G_1 \, c_{p1}}{G_s \, c_s} \qquad .. \qquad .. \qquad .. \qquad (7)$$

These definitions transform eqs. (4) and (5) into

$$\frac{d\vartheta_1}{d\xi_1} = (t_1 - \vartheta_1) \qquad .. \qquad (8)$$

and $$\frac{d\,t_1}{d\,\xi_1} = K_1\,(t_1 - \vartheta_1) \quad .. \quad (9)$$

This system of simultaneous differential equations has the solution :

$$\vartheta_1 = C_2\,e^{(K_1-1)\,\xi_1} + \frac{C_1}{K_1 - 1} \quad .. \quad (10)$$

or $$t_1 = C_2\,K_1\,e^{(K_1-1)\,\xi_1} + \frac{C_1}{K_1 - 1} \quad .. \quad (11)$$

Subscript 2 denotes the region in which the storage mass heats the cold gas. All material constants can have new values in this region except the flow of storage mass G_s and its specific heat c_s. Definitions (12) and (13) and solutions (14) and (15) below are analogous to those obtained above.

$$\xi_2 = \frac{\alpha_2\,F_2}{G_2\,c_{p2}}\,x_2 \quad .. \quad .. \quad (12)$$

$$K_2 = \frac{G_2\,c_{p2}}{G_s\,c_s} \quad .. \quad .. \quad (13)$$

$$\vartheta_2 = C_3\,e^{(1-K_2)\,\xi_2} + \frac{C_3}{1 - K_2} \quad .. \quad (14)$$

$$t_2 = C_4\,K_2\,e^{(1-K_2)\,\xi_2} + \frac{C_3}{1 - K_2} \quad .. \quad (15)$$

To find the constants C_1 to C_4 the boundary conditions must be established. The following conditions are self-explanatory :—

$$x = o \quad \begin{cases} \vartheta_1 = \vartheta_{10} & .. \quad .. \quad (16) \\ t_1 = t_2 & .. \quad .. \quad .. \quad (17) \end{cases}$$

$$x = L \quad \begin{cases} \vartheta_2 = \vartheta_{20} & .. \quad .. \quad (18) \\ t_1 = t_2 & .. \quad .. \quad .. \quad (19) \end{cases}$$

ϑ_{10} and ϑ_{20} are the inlet temperatures of the hot and cold gases, whilst eqs. (17) and (19) express the fact that storage mass from the cooling region a is introduced into the heating region b without change in temperature and is also returned to the cooling region unaltered.

These boundary conditions render the following expressions for the integration constants :—

$$C_1 = (K_1 - 1)\,(\vartheta_{10} - C_2) \quad .. \quad (20)$$

$$C_2 = \frac{\vartheta_{10} - \vartheta_{20}}{\dfrac{K_1\,(1 - e^{(K_1-1)\,\Lambda_1})}{K_2\,(1 - e^{(1-K_2)\,\Lambda_2})}\left\{K_2 - e^{(1-K_2)\,\Lambda_2}\right\} - (K_1 - 1)} \quad (21)$$

$$C_3 = (1 - K_2)(\vartheta_{20} - e^{(1-K_2)\,\Lambda_2}\,C_1) \quad .. \quad .. \quad (22)$$

$$C_4 = \frac{\vartheta_{10} - \vartheta_{20}}{K_2 - e^{(1-K_2)\,\Lambda_2} - \dfrac{K_2\,(1 - e^{(1-K_2)\,\Lambda_2})}{K_1\,(1 - e^{(K_1-1)\,\Lambda_1})}\,(K_1 - 1)} \quad (23)$$

In the above equations :—

$$\Lambda_1 = \frac{\alpha_1\,F_1}{G_1\,c_{p1}}\,L_1 \quad .. \quad .. \quad (24)$$

$$\Lambda_2 = \frac{\alpha_2\,F_2}{G_2\,c_{p1}}\,L_2 \quad .. \quad .. \quad (25)$$

The temperature distribution in the regenerator depends only on the dimensionless quantities Λ_1, Λ_2, K_1 and K_2 which we have recognised as the " dimensionless length " and " dimensionless capacity " parameters. From these a third group of dimensionless parameters can be developed as follows :—

$$\Pi_1 = \Lambda_1\,K_1 = \frac{\alpha_1\,F_1}{G_s\,c_s}\,L_1 \quad .. \quad .. \quad (26)$$

$$\Pi_2 = \Lambda_2\,K_2 = \frac{\alpha_2\,F_2}{G_s\,c_s}\,L_2 \quad .. \quad .. \quad (27)$$

A special case arises when $K_1 = K_2 = 1$ and $\Lambda_1 = \Lambda_2 = \Lambda$. This case requires a different mathematical treatment leading to the solutions

$$\vartheta_1 = \vartheta_{10} - \frac{(\vartheta_{10} - \vartheta_{20})}{\Lambda + 2}\,\xi \quad .. \quad .. \quad (28)$$

$$t_1 = t_2 = \vartheta_{10} - \frac{(\vartheta_{10} - \vartheta_{20})\,(1 + \xi)}{\Lambda + 2} \quad .. \quad (29)$$

$$\vartheta_2 = \vartheta_{10} - \frac{(\vartheta_{10} - \vartheta_{20})\,(2 + \xi)}{\Lambda + 2} \quad .. \quad (30)$$

All temperatures vary linearly with ξ as in a contra-flow recuperator of the same length parameter Λ. Such a temperature distribution is theoretically also possible in a regenerator with intermittent flow, but only in the hypothetical cases of infinite storage mass or infinite frequency of change-over.

Since the length perameter of the regenerator is exactly the same as that of an equivalent contra-flow recuperator, the pressure losses in both cases will be equal. By comparison, it has been shown that the regenerator with intermittent flow must have a length parameter Λ exceeding the theoretical minimum, and the pressure loss increases in the same proportion.

The pebble heater also shows up favourably in comparison with the recuperator, because optimum conditions of heat transfer can be established. For constructional reasons, such conditions are impossible in a recuperator. In particular, it is possible to introduce into the pebble heater a storage mass of any unit size and thus obtain any desired value of specific surface area and, hence, large heat transfer coefficients.

Another special case is characterised by the relations

$$(K_1 - 1)\,\Lambda_1 = (1 - K_2)\,\Lambda_2 \quad .. \quad (31)$$

In this case, the storage mass temperatures t_1 and t_2 at corresponding points of the two regenerator chambers are again equal. The temperature distribution is that of a contra-flow recuperator, in which, however, the heat capacity flows of the two gases are unequal.

Four examples characterised by $\Lambda_1 = \Lambda_2 = 20$ are illustrated in Figs. 2 to 5. Fig. 2 illustrates the first special case and Fig. 5 the second special case. In both the temperature distributions of the storage mass in the upper and the lower chambers are identical. This is not so in Figs. 3 and 4, which differ in the ratio K of the heat capacity flows of the gas and the storage mass. The most favourable conditions are obtained in the case of Fig. 2, where the temperature rise of the cold gas is 91 per cent of the maximum possible, whilst in the case of Fig. 3 temperature rise does not reach 80 per cent of the maximum, though the heat transfer areas are equal in both cases.

THE CALORIFIC FIGURE OF MERIT.

The author defines this as the ratio of the temperature rise in the cold gas to the difference between the inlet temperatures of the two gases :

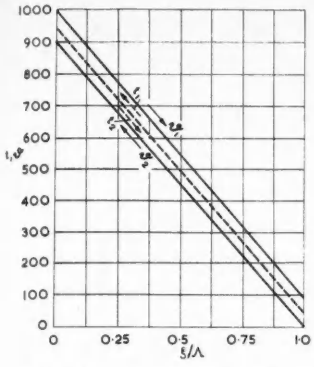

Fig. 2. $K_1 = K_2 = 1$, $\Pi_1 = \Pi_2 = 20$.

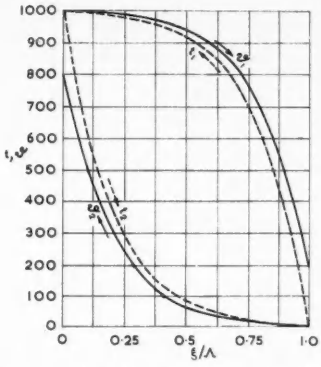

Fig. 3. $K_1 = K_2 = 1{\cdot}25$, $\Pi_1 = \Pi_2 = 25$.

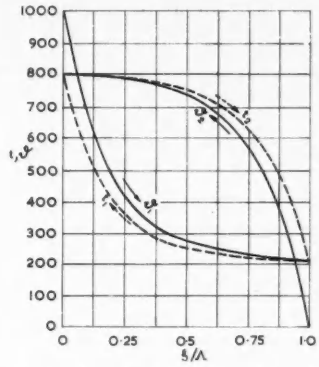

Fig. 4. $K_1 = K_2 = 0{\cdot}75$, $\Pi_1 = \Pi_2 = 15$.

Figs. 2 to 5. **Temperature distribution of the gas and the storage mass.**

———— Gas temperature.
– – – – – – – Storage mass temperature.

$$\eta = \frac{(\vartheta_2)_{x_2=0} - \vartheta_{20}}{\vartheta_{10} - \vartheta_{20}} \quad .. \quad .. \quad (32)$$

From eqs. (14), (22) and (23) the following relation is obtained :—

$$\eta = \frac{1}{\dfrac{K_2 - e^{(1-K_2)\Lambda_2}}{1 - e^{(1-K_2)\Lambda_2}} - \dfrac{K_2}{K_1}\dfrac{K_1 - 1}{(1 - e^{(K_1-1)\Lambda_1})}} \quad (33)$$

The special case $K_1 = K_2 = K$, and $\Lambda_1 = \Lambda_2 = \Lambda$, allows the following simplification to be made :—

$$\eta = \frac{2 - e^{(K-1)\Lambda} - e^{(1-K)\Lambda}}{2 - K\,e^{(K-1)\Lambda} - (2 - K)\,e^{(1-K)\Lambda}} \quad (34)$$

When $K = 1$, an indeterminate form results which is resolved mathematically into :

$$\lim_{K \to 1} \eta = \frac{\Lambda}{\Lambda + 2} \quad .. \quad .. \quad (35)$$

which shows that the figure of merit for $K = 1$ is equal to that of a recuperator of the same reduced length Λ.

Of some interest is the limiting case $K = 0$

$$\lim_{K \to 0} \eta = \frac{1 - e^{-\Lambda}}{2} \quad .. \quad .. \quad (36)$$

The same figure of merit as that of a recuperator with parallel flow has now been obtained. This case means in practice that the heat capacity flow of the storage mass is very large compared with that of the gas. The temperature of the storage mass rises to the mean value between the inlet and outlet temperature of the gas and remains constant. At $\Lambda > 10$, the cold gas is heated almost to this mean temperature whilst the hot gas is cooled to about the same value.

The opposite limiting case of $K = \infty$ is of no practical significance since it is obvious that, with vanishing storage mass, no heat is exchanged and the figure of merit becomes zero.

Fig. 6 shows the figure of merit of a regenerator with moving storage mass under the conditions $K_1 = K_2 = K$ and $\Lambda_1 = \Lambda_2 = \Lambda$. Π has been chosen

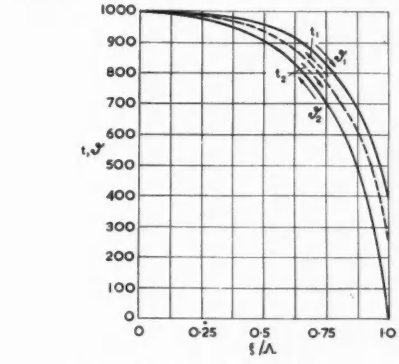

Fig. 5. $K_1 = 1{\cdot}25$, $K_2 = 0{\cdot}75$, $\Pi_1 = 25$, $\Pi_2 = 15$.

as the parameter in this illustration to show more clearly the extent to which any particular heat exchanger can be ill-matched. The fault in matching is the departure of the capacity parameter K from its optimum value of unity. All Π-curves are limited by an envelope which expresses the figure of merit of the contra-flow recuperator. A fairly accurate adjustment of storage mass flow to match the heat capacity flow of the two gases is highly desirable. In practice, it should not be difficult to reach and maintain this state since, as shown above, even small departures of the reduced capacity from unity lead to large departures of the temperature distribution from the linear pattern. The pebble heater can, therefore, easily be governed automatically.

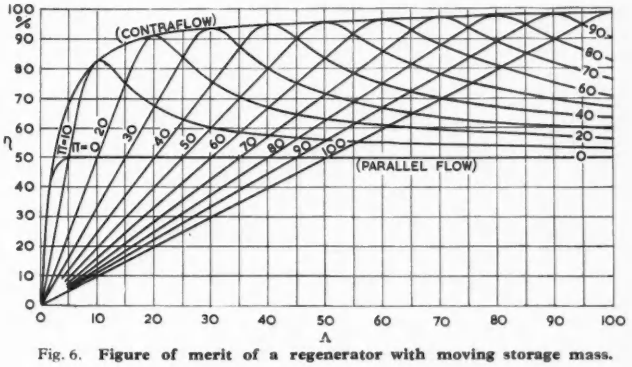

Fig. 6. **Figure of merit of a regenerator with moving storage mass.**

QUANTITY OF STORAGE MASS.

The author compares a well matched heater with an intermittent flow regenerator of equal figure of merit and so adjusted that the heat capacity flows of hot and cold gases are equal.

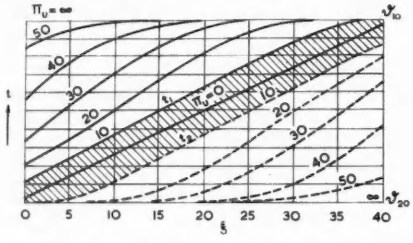

Fig. 7. **Temperature of storage mass in a regenerator with intermittent flow at the beginning and at the end of a change-over period.**

Fig. 7 shows the temperature distribution of the storage mass at the beginning and at the end of the change-over for an intermittent flow regenerator of a length parameter $\Lambda_U = 40$. The latter is defined by

$$\Lambda_U = \frac{\alpha F}{G c_p} L \qquad .. \qquad .. \qquad (37)$$

The parameter for the change-over period used in this figure is defined by

$$\Pi_U = \frac{\alpha F L}{G_{sU} c_s} Z_U \qquad .. \qquad .. \qquad (38)$$

In this, G_{sU} is the storage mass of one regenerator, and Z_U the change-over period.

During one change-over period, the hot gas is cooled on the average by $\Delta\vartheta_1$ and thus gives off the quantity of heat

$$Q = G c_p Z_U \Delta\vartheta_1 \qquad .. \qquad .. \qquad (39)$$

The same quantity is taken up by the storage mass

$$Q = G_{sU} c_s \Delta t_s \qquad .. \qquad .. \qquad (40)$$

The figure of merit of the regenerator is defined by the ratio of the mean temperature drop of the gas to the largest possible drop

$$\eta = \frac{\Delta\vartheta_1}{\vartheta_{10} - \vartheta_{20}} \qquad .. \qquad .. \qquad (41)$$

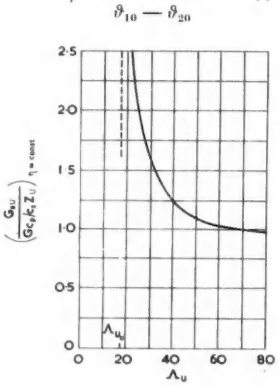

Fig. 8. **Storage mass quantity in a regenerator with intermittent flow** ($\eta = 0{\cdot}9$).

leading to the relation

$$\frac{G_{sU}}{G} = \eta \frac{c_p}{c_s} \frac{\vartheta_{10} - \vartheta_{20}}{\Delta t_s} Z_U \qquad .. \qquad (42)$$

Another relation follows from eqs. (37) and (38) :

$$\frac{G_{sU}}{G} = \frac{c_p}{c_s} Z_U \frac{\Lambda_U}{\Pi_U} \qquad .. \qquad .. \qquad (43)$$

In reference [1], H. HAUSEN finds a relation between Λ_U and Π_U for η = const, which can be expressed by presenting $\left(\frac{\Lambda_U}{\Pi_U}\right)_{\eta = \text{const}}$ as a function of Λ_U.

Fig. 8 illustrates the relation between

$$\left(\frac{G_{sU} c_s}{G c_p Z_U}\right)_{\eta = \text{const}} \text{ and } \Lambda_U \text{ for } \eta = 0{\cdot}9.$$

It shows that there is a lower limit for the length Λ_U when the storage mass becomes infinite. This is due to the fact that the temperature fluctuation Δt_s of the storage mass decreases with lower Λ_U-values and, therefore, the degree of utilisation of the storage mass is reduced.

Regenerators with a moving storage mass are governed by totally different relations. Let Z be the " traverse period " or the time which a unit of storage mass spends in one chamber of the regenerator, then the total storage mass has the value

$$G_{sB} = G_s Z \qquad .. \qquad .. \qquad (44)$$

If g_0 [kg/m²] is the weight which corresponds to 1 m² heat transfer area, then the period Z is given by

$$Z = \frac{F L g_0}{G_s} \qquad .. \qquad .. \qquad .. \qquad (45)$$

The quantity of heat exchanged in one chamber is

$$Q = G_{sB} c_s \Delta t_{sB} \qquad .. \qquad .. \qquad (46)$$

where Δt_{sB} is the change in the temperature of the storage mass in traversing one chamber. The gas temperature rises by $\Delta\vartheta$, and the gas receives the heat quantity

$$Q = G c_p Z \Delta\vartheta_1 \qquad .. \qquad .. \qquad (47)$$

Assuming optimum matching $K = 1$, previous results lead to $\Delta\vartheta_1 = \Delta t_{sB}$ and equations (46) and (47) yield

$$\frac{G_{sB}}{G} = \frac{c_p}{c_s} Z \qquad .. \qquad .. \qquad .. \qquad (48)$$

Hence, the quantity of storage mass in relation to the gas flow depends only on the ratio of specific heats and on the traverse period Z and can, therefore, be reduced to any desired degree.

The magnitude $\frac{G_{sB} c_s}{G c_p Z}$ therefore remains equal to unity, whatever the length parameter Λ, whilst the same value of storage mass would require a much larger length parameter in an intermittent flow regenerator and, hence, lead to high pressure losses.

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(2) C. L. NORTON : The Pebble Heater, *Chem. Metall. Engng.*, Vol. 33 (1946), pp. 116-119.

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A New Development in Bonded Electric Wire Resistance Strain Gauges

By A. U. HUGGENBERGER. (From *Schweizer Archiv*, Vol. 17, No. 11, November, 1951, pp. 321-332, 21 illustrations.)

The conventional electric wire resistance strain gauges are sensitive to humidity changes and their indication depends to a varying extent on transverse strains. A new type of gauge, the "Tensopickup," has been developed to avoid both these disadvantages.

ELECTRIC resistance strain gauge measurements are based on the fact that the resistance of thin wires of certain alloys (e.g., "Advance") changes proportionally with the strain imposed. The ratio of specific resistance change to strain imposed, the so-called gauge factor, is constant up to about 0·5 per cent strain, i.e., appreciably beyond the elastic range of the material. Its value is between 1·6 and 3·6 for single wire strands of various suitable materials, e.g., 2·23 for Advance. Since contact and lead resistances of the measuring circuit must not influence measurements, the total resistance of a gauge should not be less than 100 ohms, and the required small dimensions of the gauge are obtained by arranging the wire in loops. The well-known Baldwin SR-4 strain gauge (Fig. 1) shows the loop winding (2) of the resistance wire (1) to which are soldered or welded the heavier connecting leads (6) for the measuring circuit. The wire net is glued to a thin paper backing (4) by means of a special lacquer (3), and a cover sheet (8) of felt or paper protects the gauge against temperature influences and mechanical damage. A suitable glue (9) bonds the gauge to the test surface (10). The gauge factor of the completed gauge is usually smaller than that of a corresponding single straight wire because the wire is cold-worked during winding of the gauge and the looped ends are affected by transverse test strains.

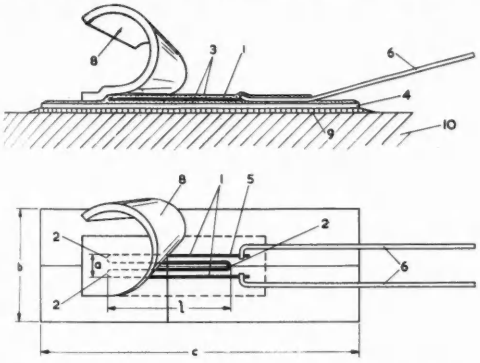

Fig. 1. **Basic design of strain gauge with looped winding, type SR-4.**

Let the gauge winding have a width a and n parallel longitudinal wire strands of active length l measured from the loop peaks (Fig. 1). If the gauge is glued to a test surface so that l is parallel with the principal strain e_1, a parallel with the transverse principal strain e_2, then the resistance change of the gauge wire indicates a strain of approximately

$$e = \frac{nle_1 + ae_2}{nl + a} = \frac{\dfrac{nl}{a}e_1 + e_2}{\dfrac{nl}{a} + 1} = \frac{\rho e_1 + e_2}{\rho + 1} \quad \ldots \quad (1)$$

According to Hooke's law

$$e_1 = (s_1 - \nu s_2)/E \quad \text{and} \quad e_2 = (s_2 - \nu s_1)\,E \quad \ldots \quad (2)$$

where E = Young's modulus, ν = Poisson's ratio, s_1, s_2 = principal stresses. The indicated strain e thus depends on the geometry of the gauge winding, the relation between the principal stresses, and Poisson's ratio of the test material. The gauge is calibrated in *uni-axial tension* on a calibrating bar stressed in simple bending or tension with a known stress s_1 and with $s_2 = 0$, so that from eqs. (1) and (2)

$$e_2 = -\nu e_1 \quad \text{and} \quad e = \frac{\rho - \nu}{\rho + 1}\,e_1 = k_1\,e_1 \quad \ldots \quad (3)$$

k_1 is smaller than the ideal value 1 and reaches it only asymptotically for large $\rho = nl/a$. The strain indication of the gauge is therefore smaller than that of a single straight wire of equal total length $nl + a$ which would indicate e_1, and gauges with differing winding factors ρ cannot give identical strain indications even if wound from the same wire material. If the test piece has a Poisson ratio ν' different from that of the calibrating bar, the strain indication of the gauge will contain an error

$$\Delta e = \frac{\nu - \nu'}{\rho + 1}\,e_1. \quad \ldots \quad \ldots \quad (4)$$

The larger ρ, the smaller is the influence of these secondary effects, so that long gauges with many parallel strands are better than short or wide gauges or gauges with only a few parallel strands. In *equal bi-axial tension*, $s_1 = s_2$, eqs. (1) and (2) lead to $e_1 = e_2 = e$. Only in this special case is the indicated strain always equal to the actual test strain. In *pure shear*, e.g., in shafts transmitting a torque, $s_1 = -s_2$, hence $e_1 = -e_2 = (1 + \nu)/E$ and

$$e = \frac{\rho - 1}{\rho + 1}\,e_1 = k_2\,e_1 \quad \ldots \quad \ldots \quad (5)$$

The error indication of a gauge calibrated in simple tension is then proportional to $k_1 - k_2 = (1 - \nu)/(\rho + 1)$. Even favourable gauges with $n = 12$ parallel strands and $l/a = 8$ indicate an error of approximately 1 per cent. On *thin-walled cylindrical vessels*, under internal pressure, $s_1 = \frac{1}{2}\,s_2$ and, from eqs. (1) and (2),

$$e_2 = \frac{2 - \nu}{1 - 2\nu}\,e_1 \quad \text{and} \quad e = \frac{\rho + \dfrac{2 - \nu}{1 - 2\nu}}{\rho + 1}\,e_1 = k_3\,e_1 \quad (6)$$

for a gauge attached in axial direction. Here the indicated strain e is larger than the axial test strain e_1 because the greater transverse test strain e_2 acts on the loop ends of the gauge. The error, proportional to $k_3 - k_1$, of a gauge calibrated in tension may become very serious. Finally, if the state of stress to be measured is such that

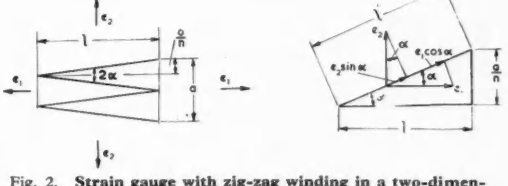

Fig. 2. **Strain gauge with zig-zag winding in a two-dimensional strain field.**

$$e_2 = -\rho\, e_1 = -\frac{nl}{a} e_1 \text{ and } e = 0 \quad .. \quad (7)$$

the gauge does not indicate any strain at all.

Gauges wound in zig-zag fashion (Fig. 2) are less subject to the influence of transverse strains. Their strain indication in simple tension, as proved from the geometry of the winding, is

$$e = (1 - \nu/\rho)\, e_1 = k_4\, e_1 \quad .. \quad .. \quad (8)$$

where e_1 = actual test strain. However, the wire is severely overstrained at the pointed ends and the required additional paper layers between wire turns increase the gauge thickness and introduce errors for the measurements of bending strains. The strain indication of the conventional resistance strain gauge thus leads to errors unless corrected by calculation.*. Moreover, the hygroscopic properties of the paper backing render the gauge sensitive to humidity changes as shown by the increase in gauge resistance during the drying period after glueing. The final resistance value of the attached gauge, reached after several hours, is about 0·2 per cent above the nominal value of the unattached gauge.

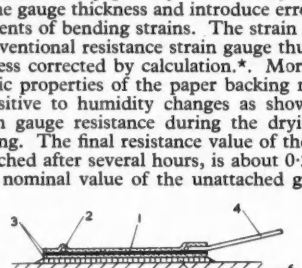

Fig. 3. **Schematic representation of the Tensopickup, a strain gauge insensitive to lateral strains.**

The GH-Tensopickup (GH-Tepic).

In 1946, Gustafsson designed a strain gauge without the disadvantages mentioned (Figs. 3 and 4). The parallel strands of wire (1) occupy the whole gauge length c and are interconnected by heavier cross wires (2) placed $^1/_8$ to $^5/_{32}$ in. from the ends. The irregular end effects of the shear forces transmitted by the glue (5) thus do not influence the active wire of length l. The resistance change of the cross wires due to transverse strain does not affect the readings, i.e., the factor k is always unity. The wires are embedded in a transparent carrier film (3). Air bubbles between gauge and test

*BAUMBERGER & HINES, Practical reduction formulae for use on bonded wire strain gauges in two-dimensional stress fields. *Exp. Stress Analysis*, Vol. 2, No. 1, 1944, p. 113.

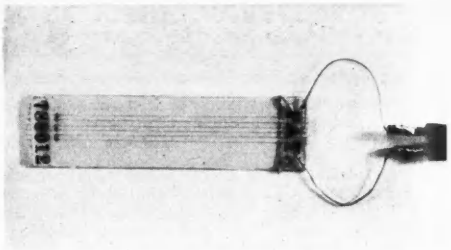

Fig. 4. **View of the Tensopickup.**

Fig. 5. **Preformed Tensopickup before attachment to a test wire of 2 mm diameter.**

TABLE I. STANDARD GH-TENSOPICKUP GAUGES, WIRE ALLOY B.

Gauge number	Active length l	Active width a	Total width b	Total length c	Resistance Ω
B$\frac{1}{2}$/120	5	3·5	10	12	120
B1/120	10	1·5	10	17	120
B2/120	21	0·5	10	28	120
B2/350	21	2·5	10	28	350
B2/500	21	3·5	10	28	500
B2/1000	22	6·0	10	28	1000
B3/350	31	1·5	10	38	350
B6/350	61	0·5	10	68	350

All dimensions in mm, approximate only.

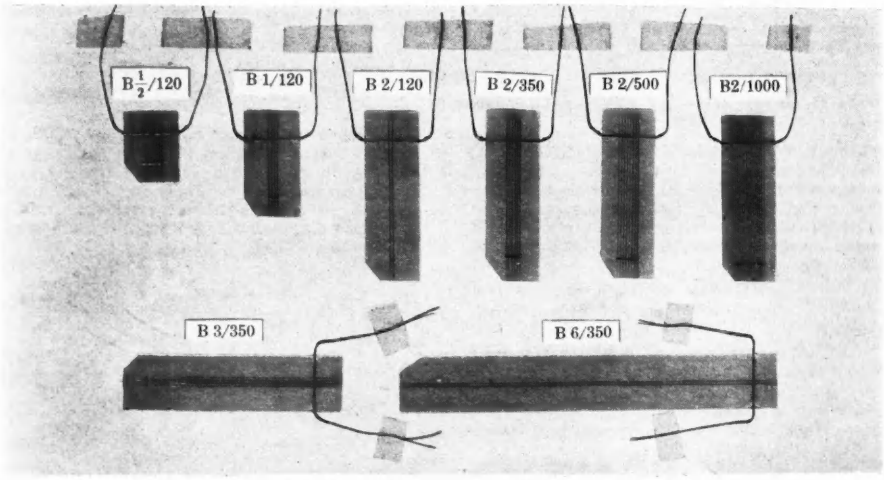

Fig. 6. **Standard Tensopickup gauges of Table I, reproduced full size.**

surface can therefore be seen and eliminated, and the gauge can be placed accurately in a given direction marked by a pencil line on the test surface. Omission of the paper base reduces the gauge thickness and places the wires nearer to the test surface. Errors in measuring bending strains are thus reduced, drying of the glue is accelerated, and dissipation of the heat produced by the gauge current improved. The temporary change in resistance during drying is less than 0·05 per cent and the final resistance value identical with the nominal value before affixing. A larger current can be used and the output signal—and measuring sensitivity—increased. The gauge is also more pliable and can easily be affixed to curved or wavy surfaces. It can be pre-formed before attachment, e.g., by tying with string to a dummy of the same shape as the test piece, heating to about 140° F, and removing after cooling (Fig. 5). Each gauge may be temperature-compensated in itself if wire strands of different materials are used so that the resulting effect of temperature changes is cancelled out. One and the same gauge may be attached without further special preparation by either air-drying or heat-drying glues. Since the strain sensitivity of the wire is not impaired by gauge winding, the gauge factors of single straight wire and complete gauge are identical for equal total active length, and calibration of gauge samples is not strictly necessary. The quality of batch manufacture, therefore, does not affect the gauge quality as critically as with the wound wire gauge. A standard series of Tensopickups has been developed (Fig. 6 and Table I) but gauges of higher resistance and greater length, up to 14 in., are made. The total width b (Fig. 3) is 10 mm ($\frac{3}{8}$ in.) for all gauges, but may be reduced where required by cutting with scissors to within 0·02 in. of the outermost wires.

For the manufacture of the Tensopickup (Fig. 7), parallel strands of wire 0·001 in. thick are stretched over a winding frame (1) secured by clamps (2) at one end, placed over rolls (3) at the other end, and given a uniform pre-tension by small weights. The cross-wires (4) are placed over these strands in positions controlled by guide rails to give a constant active gauge length. Strands and cross-wires are soldered or welded together, the binocular prism lens (5) permitting close control of the process. The carrier film is sprayed or deposited on a bar (6) which is lifted against the wire net. The wire net is then glued to the film, the cross-wires are cut so that a closed gauge circuit is formed, another layer of lacquer is sprayed onto the assembly, and the bar (6) with the assembled gauge, now embedded in lacquer, is stoved to the required degree of dryness. Calibration of the gauges is only taken as a measure of precaution and control to ensure that no wire has been damaged. Long-time tests and investigations into the effects of atmospheric humidity are proceeding separately.

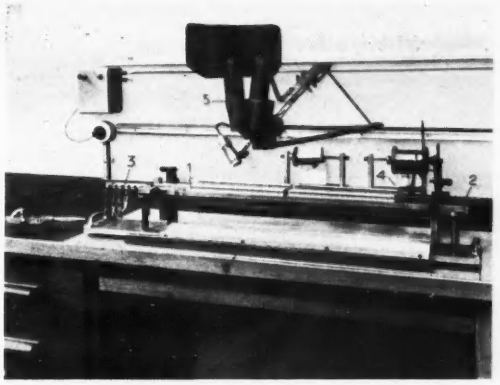

Fig. 7. **Manufacturing frame for Tensopickup.**

RUSSIA

Local Preheating by Induction in the Arc Welding of Steel Plate

By L. N. Belov. (From *Avtogennoye Dyelo*, No. 12, 1951, pp. 9-11, 6 illustrations.)

The author reviews his own research dealing with the induction heating of steel plate prior to welding. The temperature distribution in the preheated region is shown. Attainable values of power factor and efficiency are given. The condition of the welding arc in magnetic fields is studied, and satisfactory arrangements of inductors are suggested to permit simultaneous preheating and welding. Data on heating times, powers and specific energy consumptions are tabulated.

In the welding of alloy steel and of heavy components of low carbon steel it is often desirable to preheat the regions adjacent to the welding seam. Induction heating at industrial or higher frequencies (up to 2,500 cps) has in many cases been found the most suitable method. Eddy currents are induced in the component by means of so-called inductors. In the welding of plate, these inductors are of flat shape.

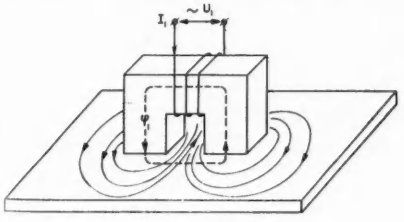

Fig. 1. **Flat, U-shaped inductor.**

In its simplest form, the flat inductor is an a.c. magnet with a U-shaped core placed upon the heated component, see Fig. 1. Experiments with adjustable inductors were carried out on low carbon steel sheet and plate of 2-31 mm thickness. The thermal properties of induction heating were studied by means of thermocouples and temperature-indicating paints. The temperature distribution in the sheet can be considered in two dimensions only. Temperature distributions characterised by isothermals of a shape such as shown in Fig. 2 are desirable. Correctly designed inductors ensure the required temperature, rate of heating and temperature distribution.

The electrical properties were studied by measuring the distribution of magnetic flux and the eddy currents in the component, with the aid of search coils and accurate voltage measurements on the surface of the sheet respectively.

The greatest density of eddy currents is found, as expected, in the centre between the poles of the magnet,

TYPICAL VALUES OF THE POWER OF AN INDUCTOR OF 500 MM LENGTH AND THE SPECIFIC ENERGY CONSUMPTION FOR THE PREHEATING OF BUTT JOINTS IN STEEL PLATES.

Low-temperature preheating to 200° C.					High-temperature preheating to 600° C.			
Thickness [mm]	Heat. time [min]	Power [kW]	Energy [kWh/m]	Spec. energy [kWh/m mm]	Heat. time [min]	Power [kW]	Energy [kWh/m]	Spec. energy [kWh/m mm]
2	1·7	4·2	0·26	0·13	2·0	17·5	1·08	0·54
4	1·9	4·4	0·31	0·08	2·5	21·7	1·88	0·47
8	6·6	4·8	1·16	0·15	4·1	22·8	3·44	0·43
16	12·7	5·5	2·56	0·16	7·8	26·2	7·64	0·48
32	23·0	7·1	6·0	0·19	14·3	30·6	16·2	0·51
64	44·0	8·7	14·2	0·22	25·7	38·4	37·8	0·59

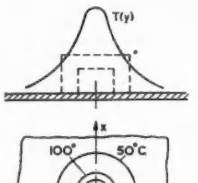

Fig. 2

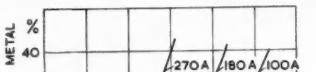

Fig. 3

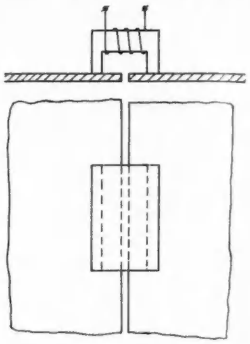

Fig. 4

Fig. 2. **Temperature distribution with concentric isothermals.**

Fig. 3. **Spluttering of electrode metal in relation to flux density of disturbing magnetic field.**

Fig. 4. **Preheating of the edges of steel plates by U-shaped inductors placed across a butt joint. Main magnetic flux of inductor crosses the joint.**

and coincides with the highest temperature of heating. It is found that the part played by magnetic hysteresis in the heating of the components varies from 1·5 to 7·5 per cent depending on the thickness of the plate and the magnitude of the flux density.

The losses and other electrical parameters of the inductors were also determined. An experimental inductor of 3-6 kW at the maximum permissible current in the winding, in plates of 2-30 mm, will have a power factor of 0·2 to 0·56, and an efficiency of 0·7 to 0·9.

Magnetic fields can have a strong effect on the welding arc. A deflection of the arc in the direction normal to the magnetic flux is observed. This phenomenon may cause a greatly increased tendency to metal sputtering. A quantitative criterion for the evaluation of interference by the magnetic field is the percentage of metal losses due to random spraying (Fig. 3). At a welding current of 100-300 A the maximum allowable value of magnetic induction is 50-100 gauss. This is confirmed by observations of the stability of the arc and the quality of the welding seam.

The disturbing magnetic field of the inductor depends on the layout of the equipment. If the inductor is so placed that the magnetic flux crosses the seam (Fig. 4), an excessive disturbing field extends as far as one metre from the inductor. This makes continuous preheating during the course of the welding operation impossible. When the inductor is duplicated, either in two separate units or in a single twin-core unit, it is possible to weld at a distance of 50-150 mm from the inductor, (Figs. 5 and 6). Simultaneous preheating and welding is therefore possible, so long as the main magnetic flux does not cross the welding seam.

Experiments have shown that the assumptions underlying the design of an inductor for a specific purpose are sound. For example, an inductor designed for 55 V takes a current of 190-220 A, consumes a power of 6·5 kW, and has a power factor of 0·5 and an efficiency of 0·9. A region of a butt joint between plates of 31 mm thickness, extending over a length of 500 mm, was heated to 260° C in the course of 30 minutes. Good agreement between analysis and test was obtained.

Data on power consumption and its relation to the parameters of the joint are given in the accompanying table, derived by analysis. The following assumptions are made: A zone around the butt joint between two plates is heated simultaneously. The length of the zone

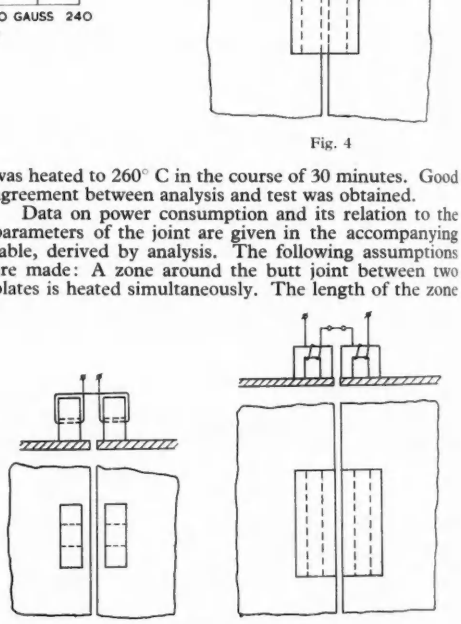

Fig. 5 (left). **Preheating of the edges of steel plates by two inductors. Main magnetic flux parallel with joint.**

Fig. 6 (right). **Preheating of the edges of steel plates by two inductors. Main magnetic flux normal to joint, but does not cross it.**

is 500 mm, its width 150 mm. These dimensions refer to the distance between the isothermals, representing the prescribed temperature of preheating, which, in turn, equals 75 per cent of the limiting temperature in the centre of the field. The table contains a column which gives the energy consumption for preheating per metre length of seam per mm thickness of sheet. This quantity is nearly constant, and can be used for an approximate prediction of energy consumption for the preheating of sheet of intermediate thicknesses not contained in the table.

CONCLUSIONS.

(1) The use of local preheating of steel plates by

means of a flat induction heater fed by current of industrial frequency is effective and desirable in many cases of welding practice.

(2) Resulting from a study of the disturbing effect of a magnetic field on the welding arc, acceptable limits of flux density in the region of the arc have been found. Design data are given for the arrangement and positioning of inductors with the least disturbing magnetic field. Such arrangement of inductors allows continuous preheating to accompany the welding process.

U. S. A.

Simple Tester for Hardness of Hot Materials

By R. F. DOMAGALA and W. R. JOHNSON. (From *Metal Progress*, Vol. 60, No. 6, December 1951, pp. 72-73, 3 illustrations.)

A RAPID, reproducible method for testing hot hardness of materials at temperatures approaching their melting points has recently been developed at the Armour Research Foundation of Illinois Institute of Technology. As shown in Fig. 1, the specimen is heated by contact with the molybdenum anvil, which in turn is heated by a $\frac{1}{8}$-in. coil of water-cooled copper tubing carrying high-frequency currents. Copper radiation shields minimise heat losses, while water flowing through copper tubing encircling the body of the tester keeps the shell cool.

A natural octahedral diamond crystal was chosen as the indenter because of its low cost and relative ease of mounting for use at elevated temperatures. The diamond was pressed into a small molybdenum block and swaged in place. The block was then machined to size, using the diamond tip orientation as the locating point. The holder was then secured to a $\frac{1}{4}$-in. sapphire rod by a piece of molybdenum wire passing through the holder and two notches on the sapphire rod.

The loading mechanism consists of a 1-in. stainless steel bellows, $1\frac{1}{2}$ in. long, with silver-soldered end plates. A steel tube enters the top plate, silver soldered, through which pressure is transmitted. During operation of a series of tests, the top plate is clamped to the cover by two nuts on each of three support rods. The bottom plate of the bellows rests on the sapphire rod carrying the indenter, which, in turn, rests upon the specimen; thus, upward movement of the bellows is prevented and the applied load is transmitted.

Loading is simple. A length of Tygon tubing leads from the stainless bellows to a mercury trap. This trap is a stout jar closed with a rubber stopper, wired down, and half filled with mercury, half with water. Two glass tubes pass through the rubber stopper, one short one reaching into the water, the other long enough to reach well into the mercury underneath. The shorter tube is joined to the Tygon tubing leading to the stainless bellows. This length of tubing is also completely filled with water.

The longer glass tube is connected with flexible tubing to a small mercury reservoir (not shown) which can be raised and lowered. In this way pressure can be increased or decreased at will, the mercury pressure being transmitted through the water to the stainless steel bellows. The presence of water in the loading mechanism prevents contact of mercury and metal at all points. In this manner loads on the indenter of any desired size up to 15 or 20 lb can be obtained.

The hot chamber is designed for use under a slight positive pressure of inert gas. A replaceable thermocouple situated well up into the head of the anvil gives a close approximation of the specimen's temperature. Since the sapphire rod is situated off-centre with respect to the anvil, and the anvil can be revolved by thumb nut and bevel gear, several indentations at one temperature or at a series of temperatures can be made quickly and easily in unbroken succession. Specimens up to about 1 in. in diameter and $\frac{3}{4}$ in. thick may be tested. Temperatures up to 2400° F have been reached with little difficulty, while higher temperatures could probably be attained if desired. Hardness values are reported in K/mm^2 where K is a constant depending upon the geometry of the indenter and the load, while mm is the average width of the indentation measured with a filar micrometer. Since the indenter is a natural diamond crystal of unique geometry, comparisons with other hardness scales cannot be made but it does furnish a reliable means of obtaining comparative hardness of hot materials.

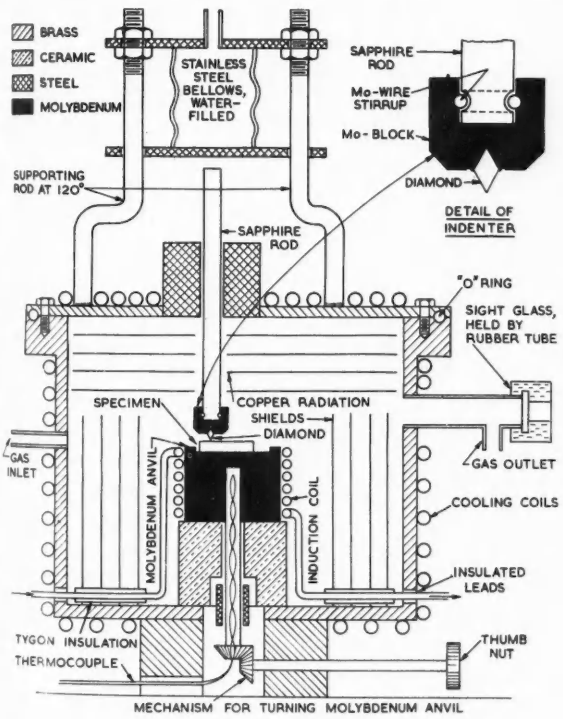

Fig. 1. **General cross-sectional drawing of hot hardness tester and detail of indenter and its mounting.**

BELGIUM

A New Apparatus for Direct Spectro-Chemical Analysis

By A. HANS. (From *Revue Universelle des Mines*, 9th Series, Vol. 7, No. 12, December, 1951, pp. 448-451, 4 illustrations.)

THE new electronic amplifier and recorder for spectro-chemical investigations was developed under the auspices of IRSIA* and built by Etablissements Radio Synthèse, of Brussels. It incorporates the following features: (a) each basic or additional element for intensity determination uses electron multiplier cells; (b) the current emitted by each cell is integrated by means of capacitances to protect it from sporadic variations of the light source; (c) the charging of the capacitances coupled to the additional elements is stopped when the charge of the basic element reaches a given reference level; and (d) voltage measurements are taken from the various capacitances connected to the additional elements.

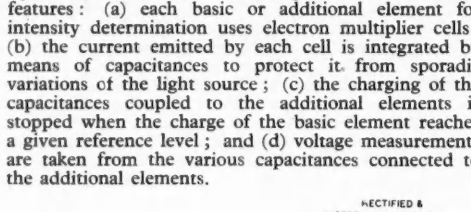

Fig. 1. **Circuit diagram for one of the additional elements coupled to the measuring bridge.**

These capacitances are connected to the measuring bridge by means of an electrometer tube (see Fig. 1), which has the advantages of an absolutely linear response and practically no grid current. These two conditions cannot be obtained simultaneously with ordinary triodes. A rotary switch successively connects the capacitances of the various additional circuits to a Wynn-Williams amplifier, equipped with a high-speed Leeds & Northrup "Speedomax" type potentiometric recorder.

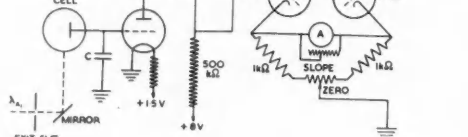

Fig. 2. **Circuit for basic (or reference) element.**

The system includes a device for correcting zero drift and slope variations in the measuring circuit. In principle, two calibrating voltages are successively applied to the amplifier. These correspond to two scale readings. Any change in these two readings indicates an alteration in the equilibrium of the bridge. The initial equilibrium is then re-established by adjusting the two corresponding bridge elements.

The electronic system is fully provided with drift-compensating devices. The system which stops the charging of the capacitance for the spectral line of the basic element is a new design, and is independent of the measuring bridge (see Fig. 2). The capacitance C belonging to the basic element is connected to a triode 955 with a zero amplification factor, which has practically no grid current. The signal, a negative pulse, supplied to the control grid of the tetrode 6AC7 with an amplification factor of 200, is amplified and transformed into a positive voltage on the grid of a triode 6J5 which is at the cut-off point. This valve operates when the positive grid voltage increases to a determined value, and allows a low-frequency alternating current, supplied by a separate generator, to pass through its anode circuit. This current then triggers two thyratrons, which act on a relay forming part of the rotary commutator device which comes into operation and successively connects the various anode circuits of the electron multiplier cells.

Correct indications are obtained only if the response of the 6AC7 valve does not vary with time. The instrument is therefore provided with an automatic calibrating device operating at the beginning of each measurement and correcting the variations of the 6AC7 by means of its screen grid. Measurements carried out with this apparatus gave full confirmation of the reliability of the system, in which the various valves operate on their dynamic characteristics so that drift is practically eliminated.

The apparatus comprises the following components: (a) a pre-sparking device; (b) a stabilised H.T. supply for the electron multiplier cells; (c) two potentiometers for the determination of each intensity calibration line; (d) an electric clock controlling the exposure time; (e) a small charging unit for the charging of the capacitances; (f) a system for the determination of the contour of the spectral lines, which is essential for the adjustment of the instrument; (g) a series of relays permitting the electronic circuits to be actuated from the source of excitation and stopping the latter at the end of the electronic cycle.

Extensive tests have been carried out with this new instrument coupled to a laboratory spectrograph. A large number of analyses were made, as well as nickel content determinations for steels, using the following experimental equipment:—Grating spectrograph, focal length 2 metres, Paschen-Runge mounting, inlet slit 40 microns. Controlled-spark source. Operating conditions: $C = 2$ microfarads, $L = 50$ microhenries, $R = 0{\cdot}4$ ohms, current 0·1 ampere, voltage 940 volts. Plane specimen (positive electrode). Counter-electrode of carbon, 120-deg. cone (negative electrode). Gap between electrodes 1 mm. Pre-sparking: nil. Exposure time approx. 25 sec. Exit slits: 200 microns for line of Fe 3222 Å, and 150 microns for line of Ni 3414 Å. Negative voltage of 740 volts for cell associated to Fe line, and 990 volts for cell of the Ni line.

To give an idea of the quality of this instrument, it may be mentioned that in two series of 20 measurements, taken with a 24 hours' interval on a specimen containing 1·95 per cent nickel, the mean (quadratic) errors obtained were 0·67 and 0·62 per cent, respectively. The intensity calibration curve remained stable between the two series of tests although the equipment was deliberately tested on the mains network at hours when the supply voltage shows its greatest variations, i.e., around 12 noon. The apparatus thus developed should be useful both in industrial laboratories and in research centres.

*IRSIA = Belgian Institute for Encouragement of Scientific Research in Industry and Agriculture.

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The Rôle of Castings in Mechanical Engineering Design

By W. HARTMANN. (From *Z. VDI*, Vol. 94, No. 3, January 21, 1952, pp. 65-73, 37 illustrations.)

When choosing between fabricated steel and castings, the designer has to bear in mind their mechanical properties, the weight and number of parts required, their performance, cost and delivery. Casting is in many cases superior to forging and welding, and sometimes composite construction will offer the best solution.

THE success of welded fabrication in recent times may well have produced the impression that less use was being made of castings. Re-designing a cast component for welding was often taken to indicate technical progress because the good points of castings were not sufficiently emphasised and sometimes the designer himself was ignorant of their superiority. A comparison between cast iron and other materials is, as a rule, only drawn when cast iron shows itself to be inferior. Its good points are often overlooked and only the last years have shown trends to improve the position.

THE SHARE OF CASTINGS IN MACHINE CONSTRUCTION.

Metal parts of machines are usually produced by casting, forging or rolling, and assembled by bolting, riveting or welding. Apart from the considerations mentioned in the synopsis above, the choice will also depend on the comparison of performances and the unavoidable wastage of raw material. National economy in material, labour and time has to be taken into account in all stages from the raw material to the finished product.

It is interesting to look at the proportion of the finished weight to the weight of raw material: of 100 per cent weight of pig iron, 71 per cent can be rolled into heavy joists but only 57 per cent into thin sheets. With forgings, the figures are still lower, with 36 per cent as an average. Crankshafts forged in one piece, of medium and heavy weight, show as little as 15 per cent. There are wide variations with castings, depending on their size, the average being 69 per cent. These figures are exclusive of machining; as a rough guide, the mean proportions may be taken as 60 per cent for castings, 50 per cent for rolled steel and 40 per cent for forgings. In this respect, therefore, castings are superior and it is not surprising that they are still widely used in machine construction.

As an example, a steam turbine of 34 tons weight contains 56 per cent of castings, namely, 15 per cent cast steel and 41 per cent cast iron. In cost, however, the cast iron parts amount to only 24 per cent, because the raw material for castings is cheaper than alloy steels and forgings and there is less wastage in machining and it costs less. About one half of the total output of foundries in Germany is going into castings for machine construction.

COMPOSITION AND MECHANICAL PROPERTIES OF CAST IRON.

Cast iron with carbon contents of 1·6 to 4·3 per cent is referred to in the following remarks, but the main range of technically important castings is that with about 2·5 to 3·8 per cent carbon. Silicon, manganese and phosphorus affect the structure, also the wall thickness and the speed of cooling. Because of its inhomogeneous structure, the properties of grey cast iron are very different from those of ductile steel, particularly with higher contents of graphite in flaked or laminated form. These differences also affect the assumptions on which the strength calculations are based.

It is clear from the stress-strain diagrams in Figs. 1 and 2 that there is no linear relation for grey cast iron and that Hooke's law, therefore, does not apply. It also follows that Young's modulus and the modulus of rigidity vary with the stress. Moreover, Young's modulus for grey cast iron, at the same numerical stress, is different in tension and in compression. There is no yield stress because this coincides with the ultimate tensile stress, which is lower than that of steel, while the crushing strength, even for grey cast iron of poor quality, is not only above its ultimate tensile strength but even above that of carbon steels in normalised condition.

Under dynamic loads, grey cast iron is to a remarkable extent insensitive to notch effects, because its graphite deposits represent numerous natural notches, both internal and external. The known values of endurance limits in bending and torsion still apply fairly accurately if polished surfaces are replaced by rough machining or even in the presence of surface notches. Steels, on the other hand, are most sensitive to notch effects, and their behaviour approaches that of brittle materials, with considerably reduced values of endurance strength. This points to a possible choice of cast iron in place of steel where machine parts are subjected to vibrations.

COMPARISON OF STRUCTURES OF DIFFERENT MATERIALS.

For members in *tension* or *compression* made of cast iron instead of steel, the required dimensions can easily be derived from the relation of Young's moduli for the two materials. Similarly, the deformations and the weights can be compared. This applies also to members in *bending*, simply supported or restrained at their ends. A great variety of machine parts belong to this group, including shafts, bolts, turbine blades, etc. Parts exposed to *torsion* are designed by similar methods, but the deflection in bending is to be replaced by the angular twist, the moment of inertia by the polar moment, and Young's modulus by the modulus of rigidity.

Plates or slabs may be restrained at one or more edges, or simply sup-

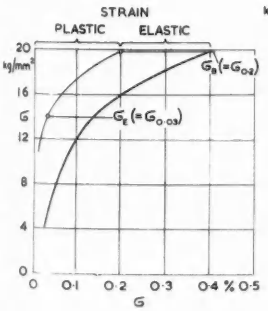


Fig. 1. **Stress-strain diagram for cast iron CI 22.**

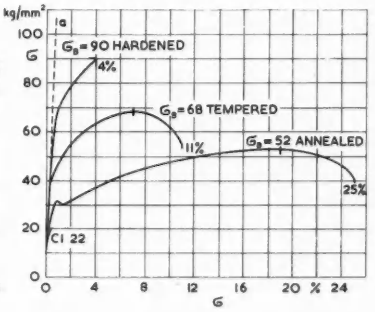


Fig. 2. **Stress-strain diagram for steel.** a = straight-line extension representing Young's modulus of $2·1 \times 10^6$ kg/cm² ($29·8 \times 10^6$ psi).

ported, but frequently they are restrained all round, e.g., in machine casings, stands and frames, boiler heads, containers and the like. Their deformation in proportion to that of steel is given by :

$$\frac{y}{y_{st}} = \frac{E_{st}}{E}\left(\frac{s_{st}}{s}\right)^3 = \frac{E_{st}}{E}\left(\frac{\sigma}{\sigma_{st}}\right)^{3/2}$$

For the cross-sectional areas or wall thicknesses :

$$\frac{F}{F_{st}} = \frac{s}{s_{st}} = \sqrt{\frac{\sigma_{st}}{\sigma}} = \sqrt[3]{\frac{E_{st}}{E}\,\frac{y_{st}}{y}}$$

For the weights :

$$\frac{W}{W_{st}} = \frac{s}{s_{st}}\sqrt{\frac{\sigma_{st}}{\sigma}} = \sqrt[3]{\frac{E_{st}}{E}\,\frac{y_{st}}{y}}$$

where E denotes Young's modulus,
y the deformation,
σ the stress,
s the wall thickness,
F the cross-sectional area,
W the weight.

The suffix st refers to steel, and letters without suffix refer to cast iron.

When designs of a machine part are to be prepared for comparing the suitability of steel and cast iron, the following conditions may be laid down :

(1) Equal deformation, i.e.,

$$\frac{\Delta l}{\Delta l_{st}} = \frac{y}{y_{st}} = \frac{\varphi}{\varphi_{st}} = 1{\cdot}0$$

where l is the increase or reduction in length in the case of axial load, y the deflection in the case of bending, and φ the angular twist in the case of torsional loads, the suffix st again referring to steel.

(2) Equal static stress.
(3) Equal factor of safety against fracture or permanent deformation.
(4) Equal sizes.

So far, similar shapes have been assumed for the designs in cast iron and steel, differing only in cross-sectional dimensions so as to satisfy the requirements of strength. However, different rules apply to the two materials, both as regards design and methods of manufacture.

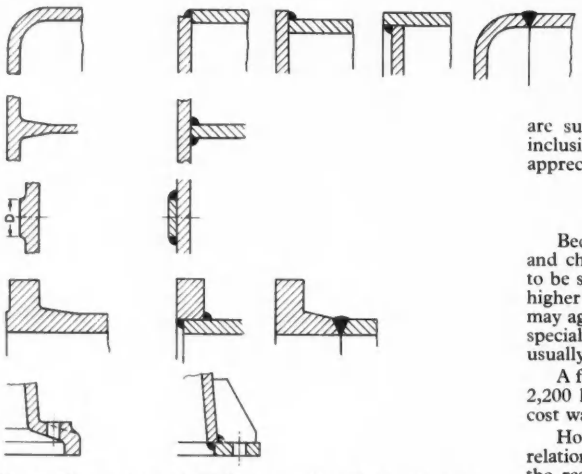


Fig. 3. **Comparison of details in cast iron** (left) **and steel plate construction** (right).

The advantages of cast iron can be summarised as follows, referring to Fig. 3. Castings are simpler, stronger and more economical for walls curved in two or three dimensions, especially when exposed to air or fluid pressure. Ribs and divisions joining the walls at an angle can easily be provided with large-size fillets along their edges which add to the rigidity and reduce the effective span of the parts. Ribs, stiffeners and brackets need not add substantially to the cost of the casting, in contrast to fabricated steel. Bolting, riveting and welding always leave some weak spots resulting in increased local stresses and notch effects. Castings can be made integral with all the necessary local reinforcements. They show high damping capacity under vibration, resonance and impact. Often the casting will be heavier than the steel plate design, but this may well be an advantage because of the shorter amplitudes and improved performances in the case of machines working by impact, such as punching presses and forging hammers.

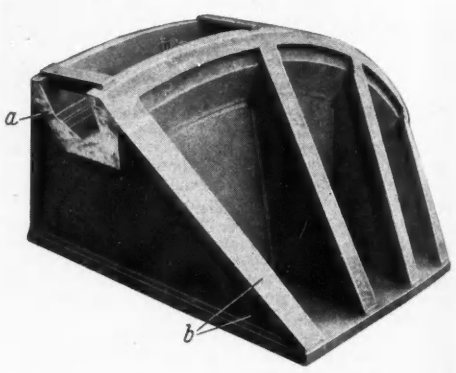


Fig. 4. **Saddle bearing for suspension bridge cables in composite construction.**
(*a*) steel casting (*b*) welded steel plates

CASTING OR FORGING ?

A detailed comparison is given for two designs of a crankshaft of 2,620 mm (8 ft. 7$\frac{1}{8}$ in.) overall length and 170 mm (6 $\frac{11}{16}$ in.) diameter. Based on a Young's modulus of $\frac{2}{3}$ for cast iron compared with that of steel St 50 (of 50 kg/mm² or 31·6 tsi ultimate strength), the deformations of the cast iron shaft are 1·65 times those of the forged shaft, resulting in increased bearing pressures. On the other hand, weight and cost of raw material and cost of machining are substantially less for the casting. Even with the inclusion of moulding costs, the casting is shown to be appreciably cheaper.

CASTING OR WELDING ?

Bedplates of fabricated steel are, as a rule, lighter and cheaper than castings. If special requirements are to be satisfied, such as increased rigidity in transport or higher damping capacity against vibrations, then castings may again compete against welded construction. Where special alloys have to be used, the welded fabrication will usually be more economical.

A fan casing of stainless steel had a finished weight of 2,200 kg compared with 5,500 kg for a casting and its cost was only $\frac{2}{3}$ of the casting.

However, the choice will finally depend on the relation of the cost of materials to the cost of labour and the result of such comparison may be quite different, say, in Germany and in the United States of America.

Casings for steam turbines will probably continue to be built as castings, because of the required rigidity.

COMPOSITE CONSTRUCTION.

There are many cases where the combination of castings and welded steel plates offers advantages, e.g., in the design of steam turbines and of electric motors, the latter using light alloy casings of high rigidity and improved heat conductivity.

The saddle bearing shown in Fig. 4 has a steel casting supported by welded steel plates, to take the suspension bridge cables.

A somewhat similar type of composite construction is illustrated in Fig. 5. The hub of cast steel is welded into the winding wheel, which is built of steel plates. In this case, failure of a welded joint may well lead to loss of human lives, and greatest care is essential.

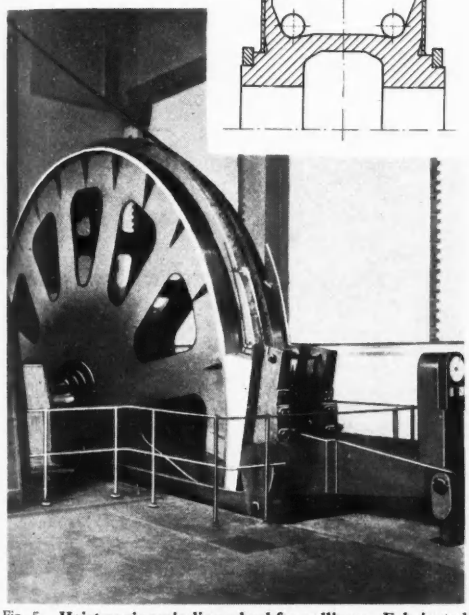


Fig. 5. **Hoist engine winding wheel for colliery. Fabricated steel plates welded to hub of cast steel.**

PRECISION CASTINGS.

These are being widely used for parts of steam and gas turbines, e.g., blades, nozzles, wheels, and pipe bends. If large numbers are required, the castings will be cheaper to produce than components of forged, rolled or pressed material. Dimensional inaccuracies are within the permissible tolerances for turbine construction, i.e., $\pm$ 1 per cent of the ratio of thickness to length of the section. The average surface roughness is 0·0015 to 0·0025 mm. If 0·001 is permissible for gas turbine blades, then only slight polishing of the blade as cast will be necessary, and even this can be omitted if a small increase of surface resistance is accepted.

DAMPING CAPACITY.

Cast blades for turbines show particular advantages in this respect. Vibrations in service, if within the range of natural frequencies, may lead to fatigue failure. The damping qualities of the casting are then of special importance. Shrouding which is often used with longer steam turbine blades may sometimes be omitted with castings, thus providing a simple basis for design calculations.

Small-size turbine wheels may even be cast in one piece. Vibrations in the sonic range, causing unpleasant noises, are also damped by castings, e.g., in the construction of gears.

TEMPERATURE STRESSES.

Because of Young's modulus being much smaller for cast iron than for steel, the temperature stresses in castings are well below those of steel parts, other things being equal. This is shown in Fig. 6, representing the

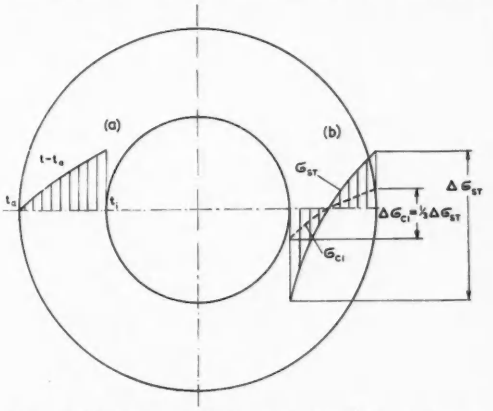


Fig. 6. **Thick-walled tube heated inside. Distribution of temperatures** (a) **and of thermal stresses** (b), **for grey cast iron and for steel.**

t_i = inside temperature t_a = outside temperature

cross-section of a thick-walled tube with internal heating. Only tangential stresses are shown, because the radial stresses, in this case compressive, are only small. In such a tube, the temperature stresses are directly proportional to the product of Young's modulus and the thermal expansion coefficient. This product equals approximately :

for grey cast iron .. .. $\alpha E = 8$ kg/cm² per °C
for structural mild steel .. $\alpha E = 25$ kg/cm² per °C.

Thermal stresses for cast iron are therefore only about $\frac{1}{3}$ of those for steel. These stresses, or the total stresses, as the case may be, are to be judged in relation to the ultimate strengths of the two materials.

CORROSION RESISTANCE.

It is well known that the natural skin of cast iron shows high resistance to corrosion. This may sometimes result in an older type of machine being superior to a later model, as actually happened with a compressor used for SO_2 gases. These gases, when condensed, formed corrosive acids, which soon destroyed the tubular steel coils in the cooler. The undamaged skin on castings, however, provides protection against corrosion.

UNFAVOURABLE PROPERTIES OF CAST IRON.

First amongst these is its growth when exposed to high temperatures. The cause of this are the deposits of graphite which expand in volume. At first, trouble was experienced with certain components of steam turbines and other heat engines, but difficulties were overcome by the use of grey cast iron varieties with limited contents of carbon, silicon, phosphorus and sulphur.

Another feature of cast iron is the difficulty of accurately producing the wall thicknesses and, therefore, the weight as designed. There is a tendency for the moulder to make the walls thicker, although no payment is made for extra weight.

The high cost of the moulds is another snag, particularly with small numbers required, and the long time of delivery may be inconvenient if replacements are needed.

Cavities and porosities are often only discovered during the last stages of machining. If the piece has to be rejected, the cost of labour is lost, delivery delayed and workshop capacity reduced.

CONCLUSIONS.

Close collaboration between drawing office and foundry can save costs. The proper design of moulds and cores provides an example amongst many others. The foundryman should keep in regular touch with the designer without waiting for special queries to be raised. The same applies to personal liaison between the foundry and the machine shop. The metallurgist must do what he can to acquaint the designer with his experience, but in the designer's language. And the designer will do well to look carefully into the properties of cast materials, particularly in view of latest developments.

U. S. A.

Reducing Noise in Machines

By D. B. CALLAWAY. (From *Machine Design*, Vol. 23, No. 12, December, 1951, pp. 122-129, 10 illustrations.)

Noise reduces worker efficiency, fatigue resistance and morale, and increases proneness to accidents. These effects are important enough for managements to consider noise control as seriously as they do other problems of safety and morale. The scope of this article is limited to the discussion of the methods of measurement, analysis and reduction of noise radiated by machines.

THE human ear responds to frequency, loudness, pitch, and timbre. The frequency range of normal hearing extends over about 10 octaves from about 20 to 18,000 cps. The audible range of sound pressures is greater than a million to one, and sound pressures as low as 10^{-10} atmosphere can be heard. The apparent loudness of noise emitted at a given pressure level is greater in the region of frequencies between 2000 and 6000 cps than at frequencies below or above this region, the relationship between sound pressure (decibels) and loudness (phons) over the audible range of frequencies being provided by the well-known Fletcher-Munson curves.

MEASURING EQUIPMENT.

There is no universal loudness meter. The sound-level meters produced commercially usually have three frequency-weighting networks corresponding to the 40, 70 and 100 phon equal-loudness contours, and after selecting the most suitable network for the measurements, the user obtains "weighted" sound-pressure level readings on the output meter. The results often show considerable errors in measuring the loudness of complex noises.

There are, however, various satisfactory techniques for the quantitative measurement of air-borne noise, all of which use some form of frequency analysis of the complex sound. Machinery noises may be classified generally as either (a) "broad band" in character, with many random frequency components (fan and blower noise), or (b) as consisting of "discrete" frequency peaks, which may or may not be harmonically related (gear and saw noise).

There are three main types of frequency analysers commonly used, viz.: (1) the constant band-width analyser, (2) the constant-percentage band-width analyser, and (3) the broad-band analyser. The first two are particularly suitable for the more accurate measurement of the relative peaks of sound spectra with discrete frequency components. With the constant band-width type, the high-frequency components are difficult to measure if they are not extremely stable in frequency.

The broad-band analyser (of the octave or half-octave type) is widely used because it is simple and gives a fairly accurate representation of the frequency distribution of the noise energy. In the case of octave bands, the upper cut-off frequency of each band is twice the lower cut-off frequency of the band; with half-octave band filters the ratio is $\sqrt{2}:1$. The entire frequency range is covered, since the filter bands are contiguous in both cases.

By means of a fairly straightforward calculation*, it is possible to obtain from the frequency analysis of the noise a single number representing the loudness of the noise. In most cases, sufficient information to guide the designer can be obtained by examining the frequency analysis of the noise. A typical frequency analysis of noise from a small internal combustion engine is shown in Fig. 1.

EXCITATION FORCES.

The exciting forces generating noise can generally be grouped into the following classes: (1) frictional forces due to rubbing, sliding or rolling contact; (2) impact forces due to sudden mechanical contact with change in direction of velocity of motion; (3) vibratory forces of rotating or oscillating members; and (4) forces due to turbulence associated with high fluid velocity in ducts, at fan blade tips, or at grilles.

The stethoscope and the stroboscope are helpful in determining the position and the relative importance of various sources of excitation. It is often useful to take measurements on various parts of a machine operating independently, i.e., externally driven. In determining the exciting forces, care should be taken to distinguish between primary sources of noise and secondary sources acting as radiators of noise at some other positions. Once the sources of excitation forces are determined, all possible means of eliminating these should be considered. Noise reduction can be attained, for instance, by substitution of fibre gears where load conditions permit, dynamic balancing of rotating parts, redesign of impacting parts to incorporate damping materials, and using improved designs for fans or grilles.

SOUND RADIATION.

The displacement amplitude x of a vibrating object with a "mechanical impedance" Z, subjected to an exciting force P at an impressed frequency $f = \omega/2\pi$ cps, is determined by the relations

$$x = P/(\omega Z)$$

and

$$Z = c + j\,[\omega m - (k/\omega)]$$

*BERANEK, MARSHALL, CUDWORTH and PETERSON: Calculation and measurement of the loudness of sounds. *Journal Acoustical Soc. of America*, Vol. 23, No. 3, May, 1951.

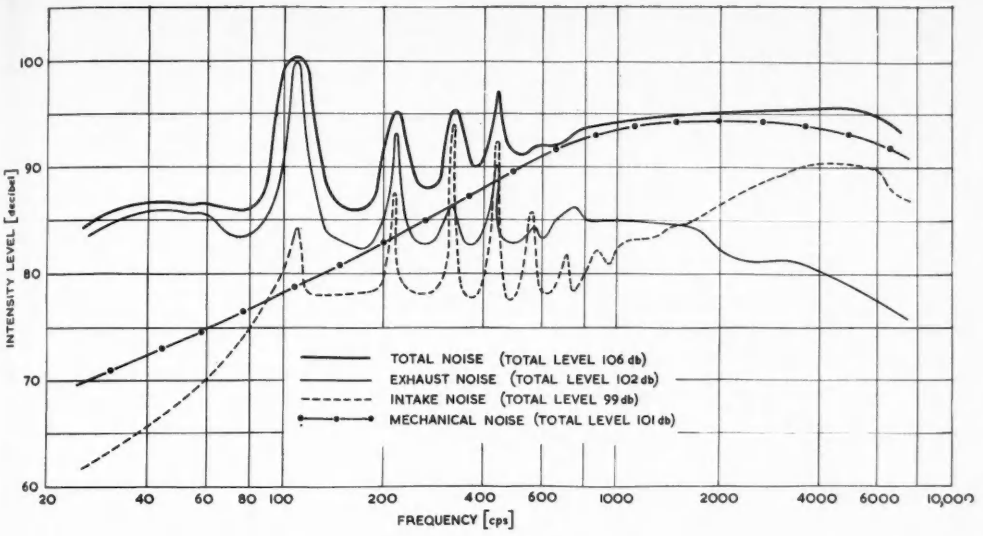
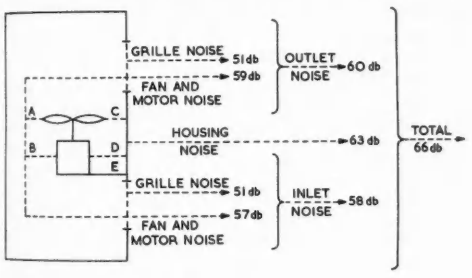


Fig. 1 (above). **Frequency analysis of noise of a small internal combustion engine determined by a constant percentage band-width analyser. Various components of the total noise were obtained by operating the machine under its own power and with external drive.**

Fig. 2 (below). **Sound-flow diagram for a portable electric heater. Dotted lines indicate paths for air-borne sound; solid lines indicate paths for structure-borne vibration.**



where c = mechanical damping, m = mass of moving parts, k = stiffness acting to restore the parts to their equilibrium position, and $j = \sqrt{-1}$. The impedance has a minimum value, and the displacement x reaches a maximum amplitude, when the mass reactance is equal to the stiffness reactance, this being the case when the object is vibrating at its resonant frequency $f_{res} = (1/2\pi)\sqrt{k/m}$. In actual vibration problems, noise radiating surfaces usually have many resonances which are not always harmonically related. The noise energy sources are often not the same parts of the machine as the radiation sources from which the sound reaches the air, and this distinction should be made wherever necessary.

The radiation of sound from a vibrating surface depends not only on the vibration amplitude but also on the radiation resistance which the air presents to the vibrating surface. For a given exciting force, the vibration amplitude is inversely proportional to the area, whereas the acoustic power dissipated is proportional to the radiation resistance, which increases approximately as the square of the surface area. This principle is applied in musical instruments which have sounding boards to increase the radiating area. This explains the disappointing results sometimes obtained by engineers who find that the noise level increases when a noisy machine is covered with an extra housing.

SOUND-FLOW DIAGRAM.

A convenient method of dealing with noise reduction problems is by means of a "sound-flow" diagram. Such a diagram indicates (1) the position of the exciting forces responsible for noise generation, (2) the paths of noise transmission to the radiating surfaces, and (3) the relative contribution of each radiation surface to the total noise.

As an example, a simple diagram for a hypothetical portable electric heater is shown in Fig. 2. The fan blades A, and the motor B, are the primary noise sources, the resulting noise escaping through both intake and exhaust grilles. The air-borne sound inside the housing is also coupled to the housing (dotted lines C and D). The fan and motor vibrations are mechanically coupled to the housing through the motor support (solid line E). The secondary noise sources are therefore the grilles and the housing. To determine the sound radiated by the housing, the inlet and output grilles can be covered with sound-absorbing material, heavy sheet metal or plywood. Measurements then show a noise level of 63 db for the housing. The fan and motor noise from each outlet can be determined by covering alternate grilles. The effect of the grilles can be determined by connecting a silencing duct to one outlet and taking noise measurements at the other with and without its grille. All measurements should preferably be carried out in a quiet, rubber-supported, echo-free room. The overall noise output is 66 db. The greatest contribution (63 db) is that due to the housing. Even if this were reduced considerably, however, the noise level will not be lower than 61 db (sum of inlet and outlet noise). The noise contribution of the grilles will become important only if the fan and motor noise is reduced by as much as 6 db.

Fig. 3 shows a further example of a more complex sound-flow diagram for a forced hot-air furnace. The solid lines represent air-borne sound paths, and the dashed lines show paths of mechanical vibrations. The investigations can, of course, be carried out with considerably greater detail, using results of frequency analyses and expressing the noise output in loudness units.

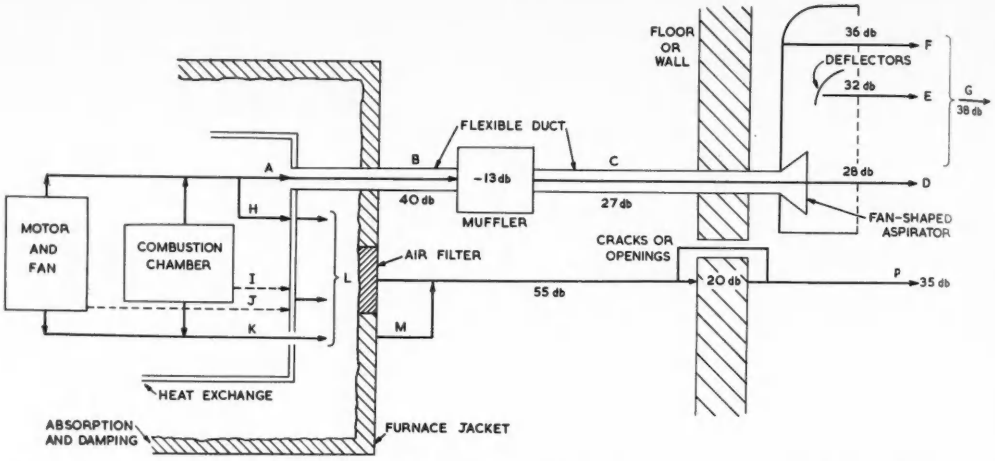


Fig. 3. **Sound-flow diagram for a forced hot-air furnace. Solid lines represent air-borne sound paths; dotted lines show paths for mechanical vibrations.**

TECHNIQUES FOR NOISE REDUCTION.

After determining the sound-flow conditions for a particular machine, the engineer is faced with the problem of making design changes to reduce the noise output, taking account also of such factors as weight, space, maintenance and cost. Surprisingly simple and effective solutions can be found in many cases. For instance, the mechanical resistance to noise can be increased by using adhesive deadening coatings, non-metallic parts, fabrics, laminated metals or other composite materials, wherever strength or wear requirements permit.

A very effective method of noise reduction is to reduce the mechanical coupling between vibration sources and radiating surfaces, by substituting " soft," i.e., flexible connecting members for rigid ones, flexible mounts for rotating machinery, and soft, resilient material between vibration sources and panels, hoods or other enclosures. For adequate decoupling, the resonant frequency due to the stiffness of the isolating member and the mass which it supports must be several times smaller than the lowest forced-vibration frequency which is to be isolated.

The noise radiation can frequently be reduced by enclosing a machine in a sound-attenuating housing. An extremely flimsy construction cannot be used, however, since for all but the lowest frequencies the sound attenuation depends mainly on the mass of the material. The housing must be continuous and any openings or air intakes required must be provided with silencers. Furthermore, the machine must be mechanically decoupled from the housing and air-borne transmission of vibration can be reduced by lining the housing with acoustical material or increasing the space between the machine and the housing.

A problem which is becoming increasingly prevalent in industry is the reduction of noise originating in, or transmitted by, air ducts or pipes of engines, heating and air-conditioning equipment, operating with high air velocities and temperatures and low back pressures. For reciprocating engines, good use can be made of metallic " mufflers " which remove the high-frequency components of the noise and smooth out somewhat the noise pulses. In ventilating and heating systems, noise reductions are obtainable by using ducts of sufficient cross-section to keep air velocity below about 1000 fpm, or by providing the ducts with an acoustical lining; by having properly designed outlet grilles, and providing adequate mechanical isolation between circulating fans and ducts. Test cells for jet engines, which exhaust 150,000 cu ft per min at 1200° F and have a noise level of 150 db, are an extremely difficult problem. The silencing structures are frequently several times the size of the cell proper and comprise acoustically treated ducts with reverse bends, expansion plenum chambers, egg-crate structures of acoustical materials in ducts or stacks, and other special designs.

HOW TO MEASURE NOISE.

When a machine is situated in a large reverberating room, standing waves may be produced at many frequencies by the sound reflected from the walls combining with direct sound from the machine. Measurement locations should then be chosen close to the machine, in general 1 to 3 times the largest dimension of the machine, with the microphone at approximately the height of the worker's ears, and a series of measurements taken at various positions around the machine may be found useful. In such cases, an octave band analyser may yield more useful data than narrow-band analysers, since variations in sound level at single frequencies due to standing waves are averaged by the many frequencies present in each band. The " background " or ambient noise due to other machines will not seriously affect the data if it is 8 to 10 db lower in all the frequency bands. Otherwise, a directional microphone, or a microphone provided with a parabolic horn of about 24 inches, giving it directional sensitivity at frequencies above 500 cps, will be found useful.

For intermittent or slowly-varying noises, a magnetic tape or wire recorder can be used to record the noise for subsequent analysis. The noise can then also be compared with later recordings taken after the noise-reducing treatment.

It is worth remembering that the annoyance value of sound cannot be described numerically. For example, an intermittent noise or one with a spectrum shifting in random fashion are judged to be more annoying than a steady noise. Hissing and screeching noises, with many high-frequency components, are generally more annoying than thuds and rumbles composed of low frequency components. Some of the psychological problems involved cannot be attacked by known engineering principles, and their solution must await the results of future psycho-acoustic research.

Three-Dimensional Flow in Axial Compressors

By J. R. SCHNITTGER. (From *Teknisk Tidskrift*, Vol. 81, No. 46, December 15, 1951, pp. 1087-1089, 5 illustrations.)

THE development of modern gas turbine techniques has increased interest in the flow conditions of axial turbo-machines. The determination of the flow characteristics for compression is much more difficult than for expansion, owing to the boundary-layer and compressibility effects, so that the development of axial compressors has stimulated further theoretical and experimental research.

A two-dimensional flow in an axial compressor has much in common with the flow around an aircraft wing. The main difference is that the wing, or pair of wings, is replaced by a series of aerofoils which constitute a cascade, as shown in Fig. 1.

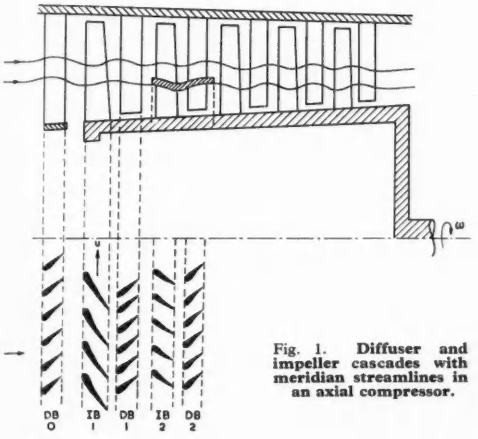


Fig. 1. **Diffuser and impeller cascades with meridian streamlines in an axial compressor.**

The three-dimensional case is more complicated because of the effect of the boundary conditions on the velocity field, so that a closer investigation is necessary. It is only in exceptional cases that the flow velocities along the impeller blades have constant values or follow a simple functional law.

METHODS FOR THE TREATMENT OF THREE-DIMENSIONAL FLOW.

The problem of three-dimensional flow has been attacked in two different ways. In the first case, the cascade is replaced by a system of bound vortices. This method is appropriate for the detailed study of the flow pattern around individual blades. For the design of the complete compressor, a simplified theory has been developed, which starts from the radial components of the equations of motion and the equilibrium between the inertia and pressure forces, using d'Alembert's principle. The equilibrium conditions then serve for the determination of the flow through the cascade at different radii.

SOME RESULTS OF THE VORTEX FIELD THEORIES.

In the three-dimensional case, considerable simplification is obtained by restricting the problem to cases with axial symmetry. The author evolved this method for axial turbo-machines, assuming a frictionless incompressible medium*.

In dealing with the flow passing the cascade, there are two main cases to be considered, viz., potential flow and vortex flow, which depend on whether the flow after the cascade is irrotational or not. The circulation around the cascade can be expressed by $\Gamma = 2\pi (r_2 c_{u2} - r_1 c_{u1})$, where c_u is the tangential velocity and r the radius at which the circulation is calculated. The simplest case of potential flow with an incompressible fluid is when the axial velocity c_a is constant and $c_u r$ is also constant for each value of the radius.

If there are radial deflecting forces in the cascade, these indicate that the bound vortex system which replaces the cascade must have annular vortex components. Calculations similar to those for the potential flow also lead naturally to an eigenvalue problem, with eigenfunctions which are a linear combination of the Bessel functions J_0 and N_0. By means of these functions the intensity of the annular vortex and the flow angles are determined for the cascade.

This case has been calculated with the aid of a solution according to Traupel. The results are shown graphically in Fig. 2, which gives the radial and axial velocity distribution as well as the path angle for the diffuser cascade. It is typical of this case that the axial velocities behind the cascade are constant over the radius, whereas the radial velocities decrease. The only transverse effect with this cascade is therefore its tangential deflection, determined by the magnitude of the circulation.

A treatment of vortex flow with the vortex field theory has been evolved by Marble, who calculated the case where the circulation around the cascade increases linearly with the radius. Unlike potential flow, this case has transverse irregularities behind the cascade for both axial and tangential velocities, whereas the radial velocity decreases as previously. The results are illustrated in Fig. 3, which shows the axial velocity

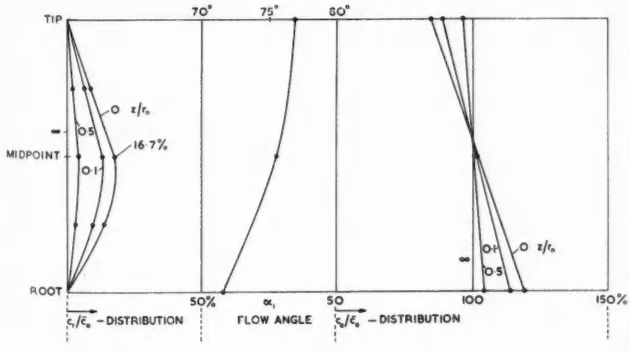


Fig. 2. **Potential Flow.**

Velocity distribution in radial and axial directions, together with flow angle α_1 for diffuser blades with a root/tip ratio of 0·5; z/r_n = axial distance from cascade with r_n = inner radius.

*This article is condensed from a paper issued to members of the Swedish Technological Association and published in its proceedings entitled *Tekniska Skrifter*, No. 149, 1951.

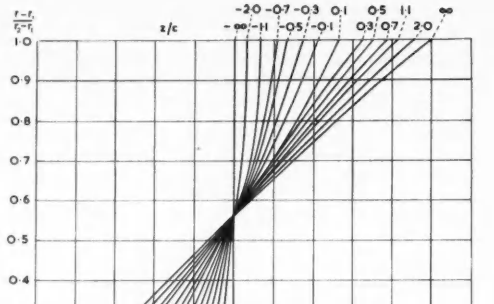


Fig. 3. **Vortex Flow.**

Axial velocity distribution with diffuser cascade c_{am} = mean velocity; c_a = local axial velocity; ξ_0 = radial vortex intensity of bound vortex field; ζ = axial width of cascade.

distribution with vortex flow. The irregular velocity distribution corresponds to the downwash effect of a three-dimensional wing.

THREE-DIMENSIONAL FLOW BY METHODS FOR RADIAL EQUILIBRIUM.

The radial component of the general equation of motion in the absence of external forces can be written as

$$\frac{\partial c_u^2}{\partial r} + \frac{1}{2}\frac{\partial}{\partial r}(c_a^2 + c_u^2) - c_a\frac{\partial c_r}{\partial z} = \frac{1}{\rho}\frac{\partial p}{\partial r} + \frac{1}{2}\frac{\partial c^2}{\partial r}$$

where c = absolute velocity, c_a = axial velocity, c_u = tangential velocity, c_r = radial velocity, p = static pressure, r = radial direction and z = axial direction.

The first term represents the inertia force due to the tangential flow. The third term is the inertia force acting on the particles while these are passing over the generally curved surfaces in the meridian plane of the machine (see Fig. 1). These forces are equal and opposite to the static pressure gradient. The remaining quadratic terms on both sides of the equation cancel each other.

In dealing with axial turbo-machines, it is, however, convenient to leave the right-hand side of the above equation unchanged and integrate over the radius. This expression denotes then the total energy gradient occurring in the flow when the energy supplied by the impeller varies along the radius. The radial acceleration

$$\int c_a \frac{\partial c_r}{\partial z}\, dr$$

can be calculated by assuming a given wave form for the flow contour, which can be approximated by a sine or cosine curve.

In this manner, a simple expression is obtained for the interference between the various cascades in the path of the flow, the shape and " potential " level of the flow curves being based on the flow characteristics both ahead of and after the passages in the cascade.

The curvature of the streamlines is extremely small. Magnified values can be obtained by using the ratio of the tip velocity to the mean velocity in the axial direction: c_{at}/c_{am}.

The value of $\int (c_u^2/r)\, dr$ is greater in front of the impeller than behind it. The flow curve is therefore determined in such a way that the radial acceleration ahead of the impeller will combine with the tangential centripetal acceleration to counteract the effect after the impeller.

Figs. 4 and 5 show a calculation for a two-stage compressor, with the various quantities in radial equilibrium indicated for a number of passages together with the function c_{at}/c_{am}. From the variation of this latter function, it is apparent that the total energy gradient of the design (which had a stage with about 50 per cent reaction over the entire radius) was not sufficient to maintain the flow at its mean value with a constant axial velocity over the radius, the ratio c_{at}/c_{am} being always less than unity whereas $c_{a\,rot}/c_{am}$ is greater than 10. This design will therefore result in a permanent displacement of the flow towards the centre line of the machine, since the equilibrium equation will only be fulfilled at a lower level.

The methods based on radial equilibrium can be developed without much difficulty to take account of compressible flow. The frictional effects can also be included and have considerable influence on radial equilibrium.

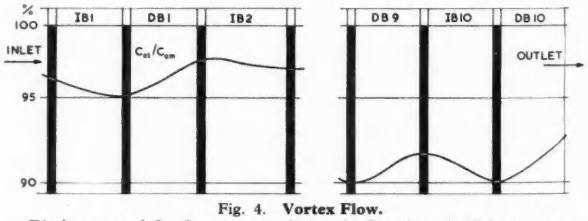


Fig. 4. **Vortex Flow.**

Displacement of C_{at}/C_{am} — curve during the flow through blade passages.

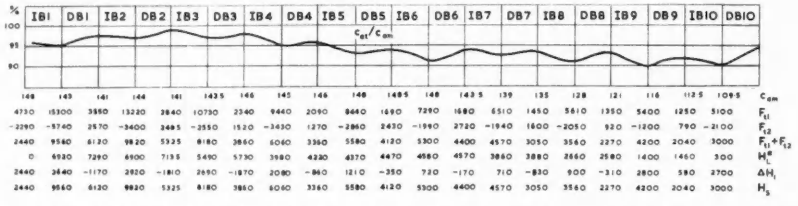


Fig. 5. **Vortex Flow.** Axial velocity distribution and radial equilibrium for a compressor with vortex flow, calculated by means of the simplified method. c_{am} = mean axial velocity; $F_{t1} = \int_L (c_u^2/r)\, dr$ and $F_{t2} = -\int_L (c_a\, \partial c_r/\partial z)\, dr$ = inertia terms; $H_L{}^*$ = difference in adiabatic work input; $\Delta H_1 = (c_a^2 + c_u^2)/2$ = expression for dynamic pressure difference; $H_S = H_L{}^* - \frac{1}{2}(c_a^2 + c_u^2)_L$ = expression for static pressure difference.

New Materials, Processes and Equipment

IMPROVED UNIVERSAL CUTTING MACHINE

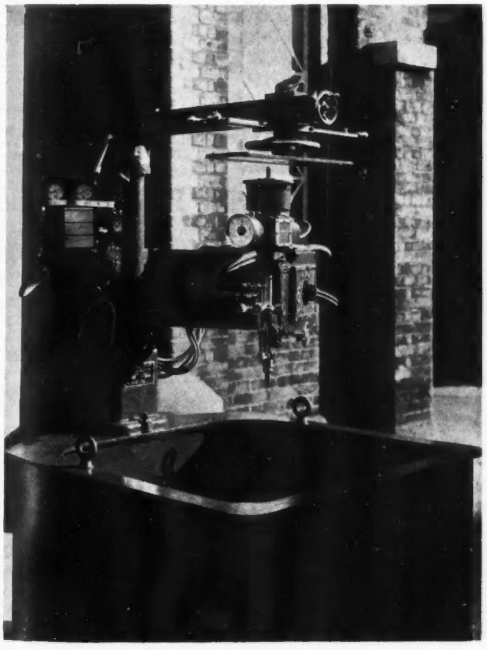
The British Oxygen Company Ltd., announce that they are producing an improved version of their well-known 36 in. Universal Cutting Machine. The general appearance of the machine is much the same as the original, since basic movement and capacity remain unaltered. In detail, however, the new machine has modifications covering the cutter and its controls, the oxygen control panel, the speed control for the template follower, and a new drive to this last. In addition, there are other small refinements.

The introduction on this machine of the M.C.6 cutter which uses the B.O.C. one-piece nozzle with the advantage of trouble-free operation and the ease with which nozzles can be changed is a most important feature. A further advance is that a powder cutting attachment can be attached for profile cutting. The speed control has been changed and a rotary rheostat replaces the old type sliding model. The " on-off " and the " forward and reverse " switches have also been altered and together with the rheostat they have been mounted on a neat panel on the outer arm. The gate arms too have been modified, the cast girderwork being replaced by a neat panelling which tends to lighten the arm and at the same time results in a cleaner appearance.

The oxygen control panel is mounted on the left-hand side of the pillar and protected from damage by a chromed steel strip. Below the control panel is a master " knock-off " valve which governs both the oxygen and the acetylene supply to the cutter, enabling all gases to be cut off with one movement.

The re-designed transmission to the tracer head incorporates an oil bath in which the oil level is visible through a glass panel.

A further worthwhile refinement is the provision of a hinged bracket on the pillar which can be fitted over the magnet roller and thus prevents movement of the arm when the machine is not in use, or when the work is being set up.



THE NEW OERLIKON UNIVERSAL LATHE

THIS new lathe, only recently developed by Oerlikon Machine Tool Works, Buehrle & Co., Switzerland, incorporates a number of interesting and unusual features in lathe design. The result is an extremely rigid and powerful machine, easily operated and ideally suited for tool room and heavy-duty production work.

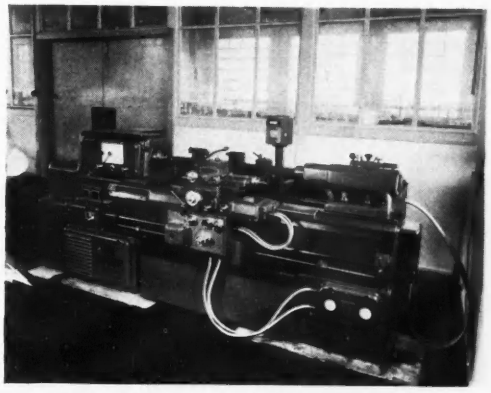
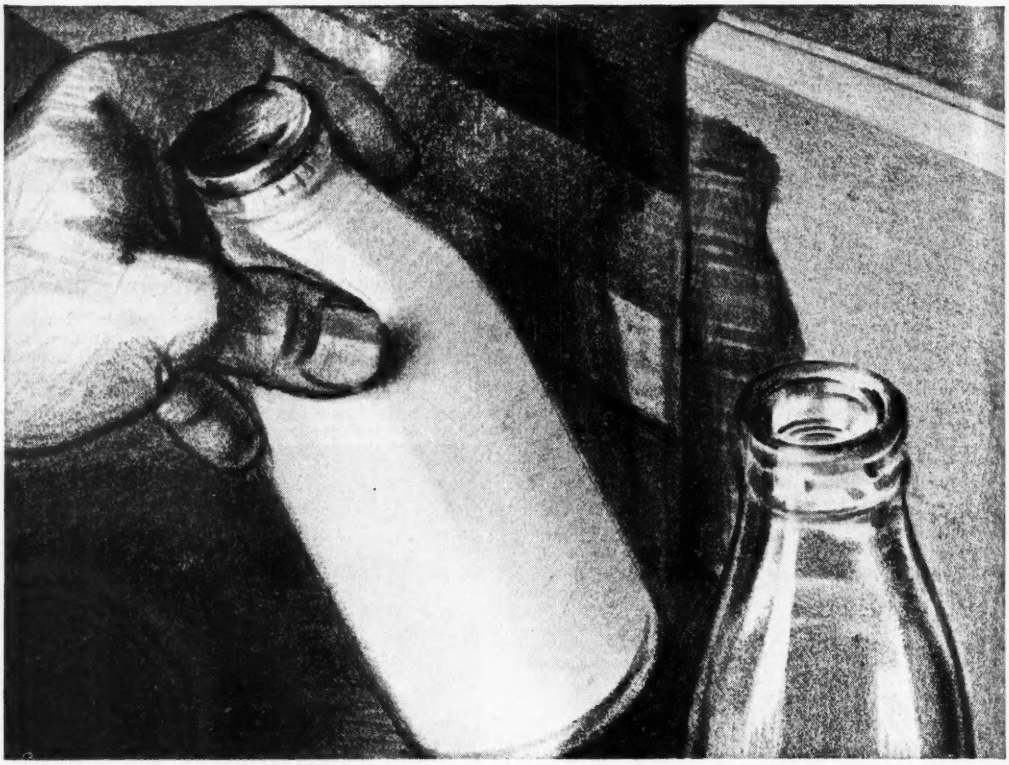


Fig. 1. **General view of the Oerlikon lathe.**

The spindle speeds are steplessly adjustable within four overlapping ranges, the total range being 38 to 2500 rpm. The speeds are set on a scale thimble, and the ranges are changed by two levers on the headstock. Speed setting and changing can be carried out while the machine is running or at a standstill. Consequently, the surface cutting speed can be kept constant when facing and, conversely, speeds can easily be varied for machining a component with difficult shoulders, grooves or stepped diameters, without stopping the machine. The feed, ranging from 0 to 0·050 in. per revolution of the workpiece, is also steplessly variable, being hydraulically operated and adjustable by a handwheel on the apron. Both these steplessly variable controls have a number of advantages, including rapid and easy operation, use of optimum feeds and speeds for any one task, giving efficient turning and reasonable cutting tool life, and elimination of the danger of accidental setting of grossly excessive speeds.

The machine incorporates a hydraulic copying device, enabling a wide variety of copying to be carried out, using master components or flat templates. Economical production is possible even for small batches through the considerable reduction of measuring and inspection and the elimination of form and other special tools. The maximum master diameter is 5½ in. and the length is limited only by the distance between centres. Change-over from and to normal operation is simple and rapid, and is effected by two levers on the apron and carriage.



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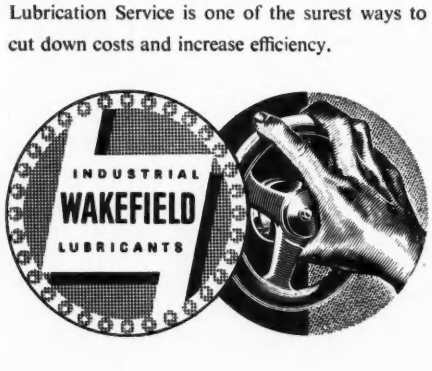
Look at that pint of milk on your doorstep. What is its butter fat content? Is its calcium content as high as it should be? To what temperatures has it been raised and lowered to kill any lurking bacilli? You don't know. But you take it for granted that your milk is as good as today's scientific food safeguards can make it.

Similarly behind every Wakefield Industrial lubricant lies a long story of scientific achievement. That is why engineers take these oils for granted. They know that the final product that reaches them embodies the sum-total of all lubricating knowledge as it stands today. They know too, from experience, that to use Wakefield Lubricants and enlist the co-operation of the Wakefield Industrial Lubrication Service is one of the surest ways to cut down costs and increase efficiency.



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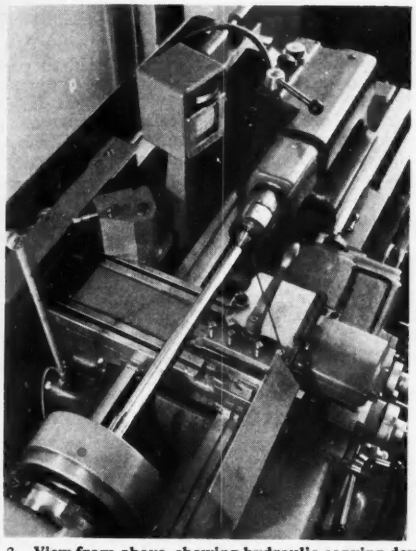


Fig. 2. **View from above, showing hydraulic copying device, tailstock and spindle speed controls.**

A screw cutting attachment using individual masters can also be provided. The master thread is copied on the workpiece hydraulically in a ratio of 1:1 or 1:2. The resulting threads are very accurate, since their accuracy is practically equal to that of the master, the length of which need only be equal to that of the required thread on the workpiece.

The strongly proportioned tailstock is also hydraulically operated and the hydraulic pressure on the back centre is variable between 880 and 2400 lbs. A safety device stops the machine automatically should the pressure drop below a certain pre-set value. The tailstock can be used for drilling, the spindle sleeve traverse being about 7½ in. Automatic lubrication is provided for the headstock; a safety device ensures that lubrication becomes effective before any movement can take place. Other parts of the machine are lubricated centrally or by means of the hydraulic oil. The electrical equipment is functional and foolproof, and ensures complete safety in operation. All switches, fuses, etc., are accommodated in an easily accessible built-in cabinet.

The main driving motor has a capacity of 25 hp and this power is almost fully available at the tool tip due to the unusually efficient design of the machine transmission. All the parts of the lathe are of robust construction to ensure absolute rigidity even under heavy cutting conditions. All main controls are centralised on the apron. The spindle is started and instantaneously stopped by a lever operating the main clutch and brake. Provision is made for using hydraulic or pneumatic chucking.

The machine is built in two sizes with centre heights of 8 in. and 10 in.; maximum turning diameters over the bed are 18 in. and 21 in. and distances between centres are 40 in. and 60 in. A 12 in. gap admits diameters of 20 in. and 22 in. The spindle bore is about 2 in.

NEW TYPE OF RED LEAD PRIMER

The acknowledged value of ordinary red lead as an anti-corrosive, rust-inhibiting, primer is well known. However, where it is intended to protect constructions exposed to sea water with bituminous solutions it is necessary to wait for months until the primer coat dries and hardens completely. Furthermore, it cannot be used as undercoat for chlorinated rubber paints because the solvents in the latter act like paint stripper. Again, chlorinated rubber red lead primers nullify the corrosion-inhibiting qualities of the red lead and bleed through subsequent coatings. The problems of these deterring factors have engaged the attention of Evode Ltd. of Stafford, who are now offering, under the brand-name "EVO-LED," an entirely new type of red lead primer suitable for application to damp or even wet surfaces which, they claim, is non-lifting or bleeding after 24-48 hours—even when overpainted with paints containing searching solvents. "EVO-LED" primer displaces moisture on any surface, absorbs it and allows it to evaporate together with the solvents during the drying processes.

PHOTOSEDIMENTOMETER

Processes employing powdered material rely for their satisfactory operation upon a consistent quality of powder. One important characteristic affecting the quality of powders is the particle size distribution. Microscopic counting can be a very tedious operation and biased by the technique of the operator. Elutriation separation is a lengthy process if consistent results are to be obtained. Bound Brook Bearings (G.B.) Ltd., Trent Valley Trading Estate, Lichfield, Staffs., in common with other firms engaged in powder metallurgy, found themselves seriously handicapped in controlling the quality of their products because of the lack of suitable measuring instruments for sub-sieve powder fineness.

The demand was for an instrument capable of handling upwards of ten samples a day and requiring the minimum of skilled attention. A survey of the work already done in this field indicated that an improved form of sedimentation apparatus was likely to satisfy the requirements. The use of a compensating optical system enabled the sedimentation to be measured photo-electrically without encountering the difficulties associated with maintaining a constant standard of illumination. The instrument was further improved by incorporating an automatic recording potentiometer in conjunction with the compensating optical system. This relieved the operator of the need to take galvanometer readings at fixed time intervals and overcame the objections of earlier instruments employing a photo-extinction turbidimetry principle.

The Photosedimentometer has been designed with the object of putting sub-sieve analysis on a practical routine basis. It is primarily intended as a particle size comparator for the purpose of maintaining the consistency of powdered materials; for, in the case of irregularly shaped particles, it does not necessarily express the result in the same terms of particle diameter as any other method of size analysis. Each of these methods rely on assumptions regarding the particle shape, and when the particles are not spherical, it all depends upon what you mean by "the diameter of an irregularly shaped particle." There are numerous corrections not affecting the reproducibility, which may be applied to the analysis so that a more exact result in terms of some classical definition of particle diameter is obtained; but, as the suitability of a specific grading will almost invariably have been agreed by other tests, these corrections have been found to be quite unnecessary in controlling powder quality from a given process of manufacture.

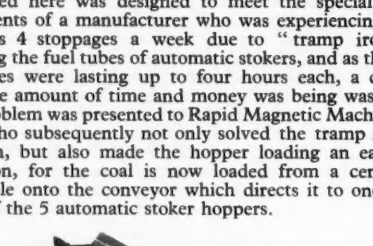
Only powders which can be made to settle out freely in some convenient liquid are suitable for analysis on the Bound Brook Photosedimentometer. These include nearly all metal powders used industrially, and most of the plastics and various silicious material, from moulding sands to crushed and ground ores. With powders which are too fine to settle out within an hour or so, even in low viscosity liquids, the Bound Brook Photosedimentometer cannot be used to give a complete

grading analysis; it will, however, give the specific surface for all powders which can be suspended in a chemically inert liquid. The specific surface, or average surface area per unit mass of powder, is perhaps the most significant single figure describing the fineness of a powder and, because it may be very rapidly determined on the Bound Brook Photosedimentometer, is often used as a quick check for suspect material before preparing a complete size distribution curve.

The instrument can also be used as a tintometer, as an absorptiometer for chemical analysis, or for measuring the opacity of filters, photographic negatives or coloured solutions, etc.

PERMANENT MAGNETIC CONVEYOR SEPARATOR

This equipment is designed to remove nuts, bolts etc., from small furnace coal. The portable conveyor illustrated here was designed to meet the special requirements of a manufacturer who was experiencing as many as 4 stoppages a week due to "tramp iron" jamming the fuel tubes of automatic stokers, and as these stoppages were lasting up to four hours each, a considerable amount of time and money was being wasted. The problem was presented to Rapid Magnetic Machines Ltd., who subsequently not only solved the tramp iron question, but also made the hopper loading an easier operation, for the coal is now loaded from a central stock pile onto the conveyor which directs it to one or other of the 5 automatic stoker hoppers.



Having a permanent magnetic pulley, d.c. voltage is not required and the only power consumed is by the ½ hp geared motor, which as a push button starter with trailing cable, for connection to standard 230 a.c. supply.

IMPROVED ELECTRICAL RESISTANCE ALLOY

Further information is now available about the new alloy with a high resistivity and a low and stable temperature coefficient, recently announced by British Driver-Harris Co. Ltd., of Manchester.

This nickel chromium alloy has a resistivity of 800 ohms per circular mil-foot and a temperature coefficient of ± 0·00002 per °C from — 50° C to + 100° C.

The higher ohmic values of this new alloy, Karma, make it possible for even smaller precision resistors to be wound at a still lower cost per ohm. The more stable resistance of the alloy permits wider applications at extended temperature ranges; its low thermal e.m.f., compared with that of copper-base alloys, gives an assurance of extreme accuracy; its superior resistance to oxidation prolongs its electrical properties. Its higher tensile strength permits faster winding speeds and its lower thermal expansion minimises distortion and movement in windings.

Karma can be soldered, brazed or welded, and arrangements are being made to supply it with the conventional insulations such as enamel and fabric coverings. It is available in wire sizes down to 0·001 in. diameter.

ELECTRICAL TUBING WITH EXCEPTIONAL FLEXIBILITY AND HEAT ENDURANCE

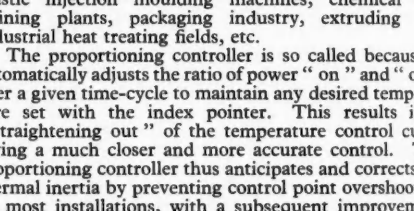
A new type of electrical tubing, said to possess exceptional flexibility and heat endurance, has just been announced by the Irvington Varnish and Insulator Company, Irvington, New Jersey. Irvington's new tubing, known as Silicone Rubber Coated Fiberglas Tubing, will withstand exposure for 200 hours at 200° C without embrittlement.

The tubing is manufactured by using selected sizes of glass braid, which are coated with silicone rubber using a special multiple coat process to ensure uniform coating and roundness.

PROPORTIONING PYROMETRIC CONTROLLER

A proportioning indicating pyrometric controller is now being manufactured by the Taco West Corporation, Chicago. It is of special interest and usefulness wherever exact temperatures must be maintained in plastic injection moulding machines, chemical and refining plants, packaging industry, extruding and industrial heat treating fields, etc.

The proportioning controller is so called because it automatically adjusts the ratio of power "on" and "off" over a given time-cycle to maintain any desired temperature set with the index pointer. This results in a "straightening out" of the temperature control curve giving a much closer and more accurate control. The proportioning controller thus anticipates and corrects for thermal inertia by preventing control point overshooting on most installations, with a subsequent improvement in production and lowering of operating costs.



The superiority of a proportioning controller over an "on-off" controller can best be demonstrated by the comparison of the temperature graphs of the two instruments. With the "on-off" controller the temperature oscillates back and forth at the set control point, and control action is accomplished by the rise and fall of the actual indicated temperature. The proportioning controller "anticipates" temperature changes of its load, thus eliminating the lag or thermal inertia of both the heating and cooling cycle. It also automatically determines the percentage of time the system requires for heating and the percentage of time the fuel or power input should be turned off to maintain the desired temperature.

One of the outstanding features of this instrument is that the meter pointer indicates the accurate temperature at all times because the proportioning action takes place in the controller section of the cirduit and does not affect the reading of the temperature indicating pointer.

(*Continued on page* 100)

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

BOLTS AND NUTS

Effect of Taper on Screw-Thread Load Distribution

By E. E. STOECKLY and H. J. MACKE. (From *ASME Transactions, U.S.A.*, Vol. 74, No. 1, January, 1952, pp. 103-112, 22 illustrations.)

The load distribution on the threads of bolts and nuts, made in the conventional constant-pitch manner and with tapered threads, was determined experimentally and theoretically. The results indicate that substantial improvement, in the order of 2 to 1, in thread load distribution can be made by tapering the thread of either the bolt or nut properly. Material improvement in bolting strength is obtained in applications which normally are conducive to little plastic flow and thus liable to result in brittle fractures, such as are encountered with dynamic loads at elevated temperatures. Ten years of operational experience on high-temperature high-pressure turbine bolting is cited to substantiate indicated improvements.

Thread Locking with Plastics

By S. S. STIVALA. (From *Machine Design, U.S.A.*, Vol. 24, No. 2, February, 1952, pp. 127-131, 2 illustrations, 4 tables.)

SELECTION of a particular type of locking fastener depends on the application, with due consideration to space limitations, accessibility, and permanence of assembly. A recent investigation has yielded a new development which offers certain advantages in commercial application—the use of liquid plastic compositions for locking threaded parts. It has been found that polyesters provide remarkable and controllable resistance to torque. The stronger polyesters produce very high torque, making the disassembly of a one-inch diameter bolt very difficult. In some applications this is desirable, while in others a somewhat different result may be preferable. It may be desired that a threaded part be capable of withstanding a limited, specified torque, but be capable of unscrewing under a somewhat higher torque. Such an application might occur in any machine assembly in which the sealer would prevent loosening from vibration but would permit unscrewing under the action of a wrench. The degree of torque resistance required can be obtained by varying the composition of the polyester sealer. As a condensed guide for the practical use of design engineers, key information on the use of polyesters as thread sealers has been put together in the form of an appendix to this discussion.

FIRE PREVENTION

Fire Tests of Bulb-Type Carbon-Tetrachloride Fire Extinguishers

By O. J. HODGE. (From *National Bureau of Standards Miscellaneous Publication* 197, *U.S.A.*, issued May 8, 1951, 8 pages, 7 illustrations.)

RESULTS are given of fire tests on samples of seven different bulb-type carbon-tetrachloride fire extinguishers ranging in capacity from 0·44 to 1·75 quarts. Six of the extinguishers were tested both for manual and automatic operation. The seventh device was tested for automatic operation only, since it was not designed for manual use.

The tests of the devices as automatic extinguishers were conducted in a room with ventilation just sufficient to permit the test fires to burn freely until the fuel was consumed, with no extinguishers present.

The test results showed that the bulb-type carbon-tetrachloride fire extinguishers, as represented by the samples tried, when operated by hand were distinctly less effective than the ordinary one-quart carbon-tetrachloride pump-gun extinguisher, and when employed as automatic devices were not effective for the protection of the enclosed space. The seven devices were tested in the number recommended by the manufacturer and six of them were also tried in double that number.

MACHINE SHOP PRACTICE

Jet-Sprayed Oil Increases Tool Life

(From *The Iron Age, U.S.A.*, Vol. 169, No. 3, January 17, 1952, pp. 97-99, 5 illustrations.)

A NEW development in the use of oil for lubrication and cooling of machining operations has been shown to increase tool life as much as 1,200 per cent. Increases in tool life up to 500 per cent have been found in tests with carbide tools, and up to 1,200 per cent with high-speed steel tools.

The development consists of a new oil and a new method of directing small high-speed jets of oil from below the cutting tool. The streams of oil pass through the space between the work and the side relief face of the tool. They are aimed at the line of contact between the work and the cutting edge.

Tests indicate that much of the oil actually passes through between the tool edge and the work, probably as a vapour. It condenses again on the chip and tool shank, and thus provides both a cooling and a lubricating action. Tests have shown that chips leaving the contact area are coated with oil, tool build-up is reduced or eliminated, nose wear is reduced, and the chip crater is more uniform. Surface finish is in most cases greatly improved. Test results have shown a reduction in surface roughness from 200 to 60 micro-inches rms.

The equipment consists of a 400-psi motor driven pump, filter, pressure-regulating valve, jet nozzle or nozzles, nozzle holders and, if desired, a special low-pressure coolant spray. The suction side of the system is connected to the existing coolant system of the machine. The discharge end is connected by flexible hose to the nozzle or nozzles.

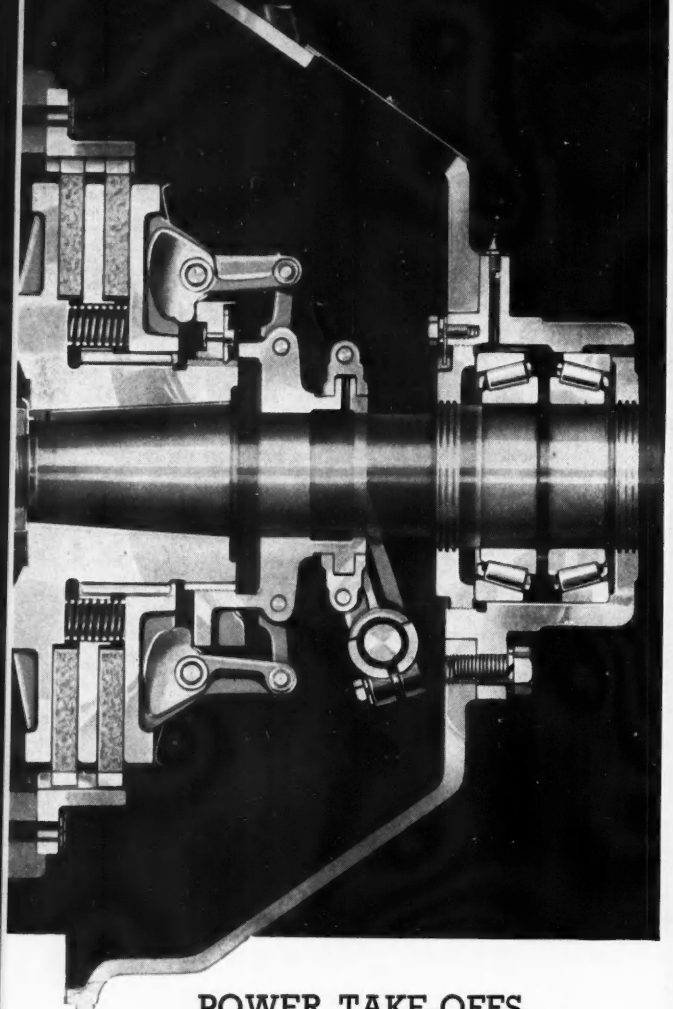
At first the method is expected to find widest use on turning operations because that is where it is easiest to apply. Suitable nozzle designs, valves, and holding fixtures are being designed for use in other machining operations such as milling, gear cutting, broaching, and certain types of drilling and grinding.

RARE METALS

Pure Vanadium — A Promising Engineering Material

(From *Steel, U.S.A.*, Vol. 129, No. 27, December 31, 1951, pp. 52-55, 7 illustrations.)

VANADIUM is one of the most recent of the rare metals to become industrially available. Pure vanadium metal has been rare, even though alloys of vanadium have



POWER TAKE-OFFS AND CLUTCHES

The well-known Rockford heavy-duty clutches and power take-offs are being made by us at Leamington Spa. They are used with industrial petrol, paraffin and diesel engines driving agricultural machines, generators, compressors, pumps, winches and other machines.

These clutches are expressly made for heavy duty, have a toggle action which holds the clutch firmly in the 'in' or 'out' position without end thrust. The only adjustment necessary can be made without the need for special tools or the manipulation of special locking devices.

Rockford clutches, and when necessary, power take-offs, are made for powers up to 13·6 h.p. per 100 r.p.m. or a maximum torque of 1,050 lbs./ft.

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been produced in quantity for many years. It has been considered a rare metal primarily because it is difficult to produce in the metallic state without the addition of alloying elements. Vanadium, however, is eighth in order of natural abundance of those metals useful for structural purposes. In this respect it ranks ahead of nickel and copper.

Pure, ductile vanadium metal can now be obtained in massive form for remelting, as well as in ingots, bars, sheets and foil. The metal is lighter than iron, has good structural properties, and resists pitting and corrosion by salt spray and sea water. It can be rolled at ordinary temperatures; cold reductions up to 85 per cent have been made without annealing. Pure vanadium machines well and is easily welded with regular shielded arc methods.

An outline of the production methods of ductile vanadium by calcium reduction of vanadium trioxide is given in the original article, and the vacuum furnace used is described in detail. Fabricating techniques, such as cold rolling, machining, welding, etc., as well as physical and mechanical properties, are discussed.

Corrosion tests have shown that vanadium is resistant to pitting and corrosion by sea water and salt spray. This resistance, in view of the metal's high elastic modulus and negligible magnetic susceptibility, might well lead to interesting applications in instruments and parts for dynamic stress on board ship or in salt water atmospheres.

STRENGTH OF MATERIALS

Fatigue Testing of Welded Joints

By V. I. SHABALIN. (From *Avtogennoye Dyelo, Russia*, No. 11, 1951, pp. 4-5, 6 illustrations.)

ECONOMICAL design in all branches of engineering brings into prominence the fatigue strength of structural, elements. Experimental evidence requires lengthy testing, but is indispensable. Great value attaches to well-founded methods of shortening tests.

The author recalls that general experience with fatigue failures shows that the more brittle the material the less the number of stress reversals needed to establish its endurance strength. He states that welded joints and their neighbouring zones generally contain material of higher brittleness than the virgin metal. Hence, a lower number of stress reversals is adequate. For steel, 5 million reversals is recommended. The author's recommendation is supported by tests on a large number of samples of "Chromansil". Fatigue tests at room temperature, at -70° C, and again at room temperature but following a thermal treatment of welded samples in liquid oxygen (-183° C), were also carried out. The above-mentioned thermal treatment converts the residual austenitic into an all-martensitic structure.

All these tests prove that a welded steel sample which has withstood 5 million stress reversals will withstand practically an infinite number of reversals. They also re-emphasise the general rule as to the relation between brittleness and minimum number of cycles. The artificially induced brittle conditions at sub-zero temperature give much higher fatigue strengths at large numbers of reversals, but the S-N curve falls much faster and levels out at 1 million reversals.

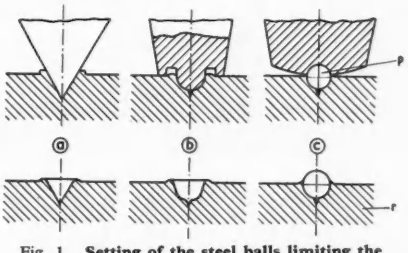


Fig. 1. **Setting of the steel balls limiting the gauge length.**

Metallographic and microscopic examinations of welded joints show that in arc-welded steel joints, fatigue strength is determined mainly by the metallographic structure of the metal in the zone adjoining the seam. The weakness is due mainly to the formation of microscopic gas inclusions. In gas welding, these inclusions are much less frequent, and fatigue strength is decided by the internal stresses set up in the seam itself during and after the welding process.

STRESS ANALYSIS

The Tensotast, a New Tensometer

By A. U. HUGGENBERGER. (From *Schweizerische Technische Zeitschrift*, No. 50, December 13, 1951, pp. 847-848, 3 illustrations.)

FOR many structural measurements, where the extreme accuracy of the usual tensometers is not required, a removable extension gauge, suitable for use at any desired point or time, and for measurements sometimes extending over months or years, would be of great advantage. The Tensotast developed for this purpose measures extensions over a gauge length of 20 mm (about $\frac{3}{4}$ in.) limited by two fixed stainless steel balls of $\frac{1}{16}$ in. diameter. A double-pointed centre punch first makes two indentations 20 mm apart (Fig. 1); these are widened out to a semi-spherical shape by special punches; the steel balls (*p*) are then inserted and the protruding borders of the indentations closed up so as to trap the balls safely even during plastic deformation of the test piece *r*. The gauge (Fig. 2) consists of a rigid frame *c* with the fixed measuring leg *a* and fulcrum *e* for the movable lever *b* carrying the second measuring leg. A tension spring *g* ensures contact of the end *i* of lever *b* with the foot *h* of a precision dial gauge measuring 0·001 mm per division with a total travel of 5 mm (0·2 in.). Two smaller dials indicate 0·1 and 1 mm travel per division. When the gauge is not in use, the end *f* of lever *b* is pressed against end *n* of hand lever *k*, the travel of which is limited by pin *o*. The dial is freely surrounded by a housing *d* connected to frame *c*, so that when the gauge is held by hand, the dial reading is not influenced by hand pressure. When a measurement is taken, the fixed point *a* is first set on one steel ball. The lever *k* is then operated by the little finger of one's hand until, on simultaneously tilting the gauge, the indentation of leg *b* comes to rest securely on the other steel ball. The

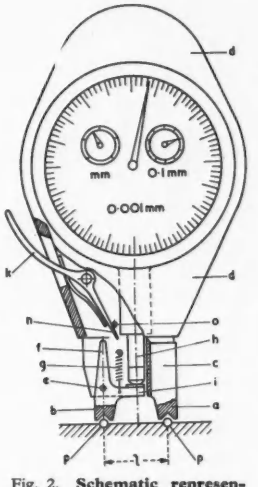
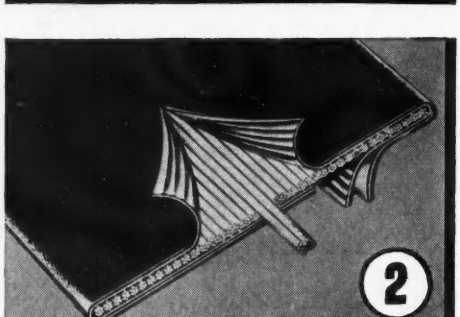


Fig. 2. **Schematic representation of the Tensotast.**

BELTING AND HOSE

that can carry the load . . . and keep on carrying it



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1 GOODYEAR CONVEYOR BELTS

The "Stacker" belt, illustrated here, is designed for installations which handle highly abrasive material and subject the belt to frequent flexing. Its tough, resilient cover " gives " under impact and resists cutting. Superior frictioning between the high-grade plies ensures that severe flexing will not cause ply separation.

2 ENDLESS CORD TRANSMISSION BELTS

Specifically built for modern high-speed, small-pulley machinery, Goodyear Endless Cord Transmission Belts incorporate a patent *balanced* construction of load-carrying cords. Their H.P. capacity is 33⅓% greater than ordinary belts of equivalent thickness; they are genuinely endless; and have an unusual degree of flexibility which gives a firm grip on small pulleys at high speeds.

3 WRAPPED PLY HOSE

This Goodyear Hose is built from high-grade rubber tube wrapped in tough rubberized fabric for greater strength. A protective cover of bruise- and abrasion-resisting rubber assures lasting wear. And scientific arrangement of the fabric plies minimizes kinking. Intended for general service this wrapped ply hose gives long life under the most arduous conditions. It is typical of the several styles of Goodyear hose built for delivery of air, water, steam, chemicals, foods, paint, solvents or petroleum products.

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reading is taken while the gauge is pressed uniformly against the test surface. The dial face is protected by a cover, which is opened for reading and carries a mirror on the inside, so that readings can conveniently be taken from above the gauge. The dial gauge is normally so arranged that extensions or contractions of up to 1 mm can be measured on a 20 mm gauge length; for special purposes, however, the full range of 5 mm can be used. The reading accuracy is ± 0·001 mm or one division for the normal design, and ± 0·003 mm for a travel beyond ± 1 mm. With some experience, the setting error can also be kept within ± 0·001 mm. A calibrating gauge length may be used as a check on the proper working of the instrument. Any variations in gauge readings that may occur over very long periods can then be eliminated by taking the extensions as the difference between the test reading and a simultaneous reading on the calibrating bar. Temperature influences can be eliminated if the calibrating bar is made of the same material as the test piece and kept in its immediate vicinity.

THERMODYNAMICS

A New Method for Determining the Static Temperature of High-Velocity Gas Streams

By J. A. CLARK and W. M. ROHSENOW. (From *ASME Transactions, U.S.A.*, Vol. 74, No. 2, February, 1952, pp. 219-228, 9 illustrations.)

THE general problem of measuring the static temperature of gases flowing at high and low temperatures and at low and high velocities is reviewed. Thermodynamic methods are discussed and a new method is presented with experimental results. This proposed temperature-measuring method has several important and desirable features: (a) The calculated static temperature is practically independent of gas composition insofar as composition is characterised by the specific-heat ratio k; (b) like the thermocouple, the temperature determined by this method is a "point" value, not a mean value at the flow cross-section where the measurements are made; (c) unlike the thermocouple, the method improves in accuracy as both the gas temperature and velocity are increased; and (d) the instrument required is relatively simple to build, is not subject to the effects of corrosion, and is extremely rugged when installed. The instrument requires no special handling and can be installed conveniently and easily in ducts of any shape or in a stream of unconfined gas.

WELDING

Welded Joints Between Stainless and Low Carbon Steels

By N. Y. PALTCHOOK. (From *Avtogennoye Dyelo, Russia*, No. 12, 1951, pp. 1-4, 5 illustrations.)

IN the construction and repair of chemical plant, welded joints are often formed between fittings made of low carbon steel and stainless steel equipment. An investigation into the corrosion properties of such joints in the presence of the vapour of certain chemicals yields the following findings and recommendations.

Tests were made on a number of experimental Tee joints considered to be representative of the joints occurring in practice. These sample joints were tested for mechanical properties, metallographic structure, surface corrosion, and intercrystalline corrosion. The yield point and ultimate tensile strength of stainless low carbon joints were equal to those of unwelded steel. It is recommended that stainless steel electrodes with a 22/13 or 25/13 nickel/chromium content should be used. The metallographic structure of the joint shows clearly distinguishable zones from the purely austenitic structure of the stainless steel through a number of transition states to the ferritic structure of the low carbon steel.

The resistance against surface corrosion in the presence of the vapours of typical solutions (10 per cent HNO_3; 20 per cent NaCl; 10 per cent HCl; 20 per cent NaOH) does not reveal any specific influence of the welding process. Corrosion measured by the loss of metal per unit of surface area per hour is represented by an index of 2, which denotes satisfactory corrosion resistance. Tests have shown the complete absence of intercrystalline corrosion in any of the zones of the welded joint. The stainless steel component does not lose any of its corrosion-resisting properties.

Seam Welding of Monel Metal

By E. F. NIPPES and G. M. SLAUGHTER. (From *The Welding Journal, U.S.A.*, Vol. 30, No. 11, November 1951, pp. 537s-544s, 26 illustrations.)

THIS research covers the seam welding of Monel sheet in five different thicknesses from 0·010 to 0·062 in. Optimum conditions were determined for each thickness of material and the factors determining the proper values of the welding variables are discussed. The criteria of satisfactory seam welds are: (1) No porosity in the weld nugget, (2) good nugget penetration, (3) sufficient weld overlap to ensure a pressure-tight seam and (4) a wide current range. The welding current range varies with the thickness, the upper limit being determined by the point at which expulsion occurs for the thicker gauges, and the point at which electrode sticking occurs with thicknesses below 0·062 in. The pillow test was found to be a valuable aid in determining the strength and pressure tightness of seam-welded joints. Methods of decreasing the tendency for sticking of the Monel sheet to the welding electrodes are discussed.

THE GEOGRAPHY OF STEEL

(*Concluded from page 72*)

speedy enough to make the 9,000 miles round trip within a couple of weeks. Before long, the company expects to be exporting something more than two million tons annually.

The development of the Rhodesian ores is likewise under way. Here, the initiative is in British hands, but the deposits are so large that they could well become of international importance.

The most commonly employed alloying elements are manganese, vanadium, nickel, molybdenum, cobalt, chromium, tungsten and titanium. Without these, the production of high-speed tools, engine parts, guns and other equipment subject to intense heat would be impossible. So important are these alloys nowadays that their supply has become a matter of almost as much concern to the steelmaker as the supply of iron ore. Yet, because the quantities involved in a given metallurgical operation are small, their importance is frequently overlooked by the layman.

While the U.S. has always had more than enough iron ore, it is not as well-placed for ferro-alloys. The industry may have to look beyond the Americas for supplies of scarce ferro-alloys, but without exception its deficiencies in such commodities can be made good by friends in the free world.

There is nothing in the present situation to suggest that the days of America's metallurgical dominance are numbered. On the contrary, taking the country as a whole, and keeping in mind the vast mineral and fuel supplies to which it is tributary, it is difficult to see how the U.S. steel-making potential can be matched by any nation or existing association of nations for many years to come.

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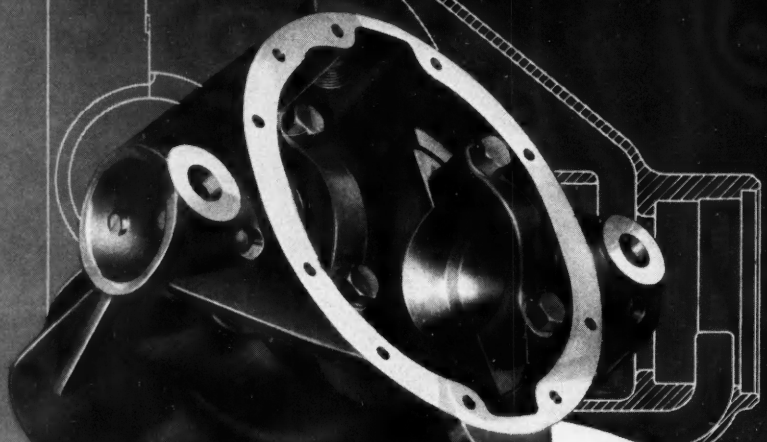

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NEWS OF THE MONTH

PERSONAL

Mr. Fraser W. Bruce has been appointed managing director of Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C.2, to succeed **Mr. Kenneth Hall** who has accepted an appointment in the Head Office of the Aluminium Ltd. Group of Companies in Montreal.

Mr. H. L. Collins has been appointed manager of the controls and soot blower division of Hopkinsons Ltd., Huddersfield, in succession to **Mr. W. B. Dale** who retired. **Mr. S. Brook** has been appointed manager of the soot blower department.

Mr. Charles Connell, M.A., M.I.N.A., chairman of Charles Connell & Co. Ltd., Scotstoun, Glasgow, has been elected President of the Shipbuilding Conference in succession to **Mr. J. Ramsey Gebbie, C.B.E. Mr. J. W. Elliott, C.B.E.,** chairman of Swan, Hunter and Wigham Richardson Ltd., Wallsend-on-Tyne, has been elected vice-president.

Mr. W. G. Copestake, A.M.I.Mech.E., has been appointed chief engineer of the City Transport Department, Empire House, Gt. Charles Street, Birmingham.

Mr. Ambrose Firth, of the Brightside Foundry & Engineering Co. Ltd., has been re-elected President of the Sheffield and District Engineering Trades Employers' Association, 59 Clarkehouse Road, Sheffield 10. **Mr. Frank Hepworth** has been appointed secretary. **Mr. T. Goddard Mander** is director of the Association.

Mr. R. W. Flux, A.M.I.E.E., has been appointed to the newly created post of chief engineer of the transformer department of Bruce, Peebles & Co. Ltd., Edinburgh 5.

Mr. D. M. Glendinning, B.Sc., A.M.I.C.E., F.Inst.P., formerly chief engineer for Lobitos Oilfields, chief engineer for Anglo-Egyptian Oilfields and chief engineer for Fina Petroleum Products, has been appointed manager of the new refinery of Vacuum Oil Co. Ltd., Croyton, Essex.

Mr. A. B. Graham, manager of Henry Wiggin & Co. Ltd., Zenith Works, Thornliebank, Glasgow, has been elected to the Delegate Board of the Company.

Mr. L. E. Meeks and **Mr. H. R. Walton, B.Sc.,** both previously directors of Electroflo Meters Co. Ltd., have recently joined Elliott Brothers (London) Ltd., Century Works, London, S.E.13.

Mr. A. R. Northover, M.I.Prod.E., director and works manager of Hoover (Washing Machines) Ltd., Merthyr Tydfil, has been elected President of the South Wales and Monmouthshire section of the Institute of Industrial Supervisors.

Mr. G. Darnley Smith, managing director of Bush Radio Ltd. and Cinema-Television Ltd., has been elected chairman of the Radio Industry Council. **Mr. G. A. Marriott,** director of the Marconi-Osram Valve Co. Ltd., has been elected vice-chairman.

Mr. A. P. Wickens, deputy chief engineer at the Fighting Vehicles Design Establishment, Chertsey, Surrey, has been appointed chief engineer for Armament Design, Ministry of Supply.

BUSINESS NOTES

The Quasi-Arc Company Limited, Bilston, Staffordshire, announce that as from 1st April, 1952, sales and service of Unionmelt automatic welding plant, powder and wire will be transferred to their Associated Company, Fusarc Limited, Team Valley, Gateshead-on-Tyne, 11.

The Dartmouth Manufacturing Co. Ltd., West Bromwich, have acquired the share capital of Charles Thomas & Co. Ltd., edge-tool manufacturers, Aston Manor, Birmingham.

Vickers-Armstrongs Ltd., Vickers House, Broadway, London, S.W.1, have purchased the works and plant of Hyland Ltd., Wakefield. The plant will provide additional capacity for the production of infinitely-variable speed hydraulic gears and pumps, manufactured at the firm's Elswick works.

Eumuco (England) Ltd., Beverley Works, Barnes, London, S.W.3, announce that they have moved to larger offices at 12 Great Portland Street, London, W.1, Tel.: MUSeum 2596-7.

Bakelite Ltd., 18 Grosvenor Gardens, London, S.W.1, announce that their Northern sales offices are now moved to more spacious quarters at The Royal Exchange, Manchester 2. Tel.: Blackfriars 5174-7.

The Denbigh Engineering Co. Ltd. announce that their sales arrangements with the machine tool trade in the United Kingdom will not be affected by the arrangement with Fenter Ltd., Birmingham, who will sell the Denbigh machine tools overseas, excluding Australia and New Zealand.

Mr. C. D. B. Williams, of Walton, Warwick, who has been closely associated with the Van der Horst interests in the United Kingdom for the past fifteen years, and who has been to a great extent instrumental in bringing about the Van der Horst—B.S.A.—Monochrome link-up recently announced, will continue to represent not only the Dutch and American Van der Horst interests in this country, but also Monochrome Ltd. in their extended sphere of activity in connection with cylinder bore plating.

CHEMICAL INCREASES ENGINE LIFE

Scientists believe that if small quantities of a chemical are added to aviation petrol, it will increase the serviceability of piston-engines and mean great savings for the world's airlines. Emergency engine changes will be much less likely and non-scheduled spark-plug changes may be cut by as much as 90 per cent.

The effect of the chemical—tricresyl phosphate—is to counter the effects of lead deposits, particularly on the valves and sparking plugs. It will increase the life of plugs and valves many times over.

The quantity of lead, in the form of tetraethyl lead, added to aviation gasoline to raise the octane number of lower-grade fuel is considerable—in a 1,200 horse-power engine running for 1,000 hours, it equals about half a ton of metallic lead. Most of this goes out in the engine exhaust, but some remains and causes fouling.

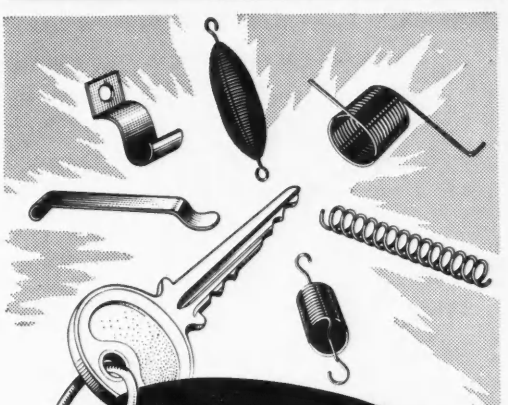
The new "additive" was discovered simultaneously by two teams of Shell scientists working independently in Britain and America—and after hundreds of tests including over 4,000 hours of successful flight-testing.

Three airlines are now carrying out tests—British Overseas Airways Corporation, KLM and American Airlines.

THE FERRANTI COMPUTER FOR TORONTO UNIVERSITY

Ferranti Ltd., who made the "Electronic Brain" which is installed in the University of Manchester, have now completed the second machine of a series which they are producing. It has been ordered by the National Research Council of Canada for the University of Toronto.

The Manchester machine now works twenty-four hours a day on a wide variety of problems. It is being used to perform scientific and engineering calculations, which because of their complexity, involve a vast amount of computation. Its use may be expected to speed up all large-scale figure work. Machines of this type work automatically, and in doing so use large numbers of figures and retain those results of calculations which they may later require.



It isn't a magic key or anything like that. It just so happens that we have been called in on so many tricky questions over the last thirty years that we now know the answer to most of them. Wouldn't it be a good idea to see us about your new project? *Established 1919. A.I.D. approved.*

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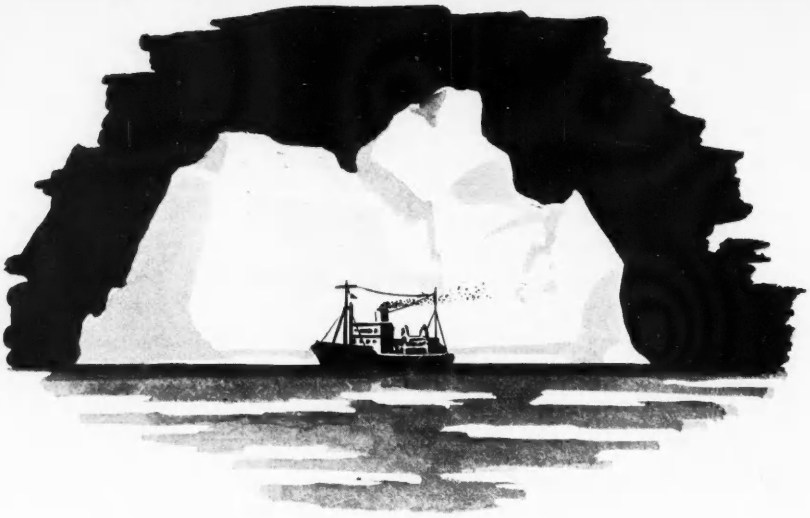

Some propellers don't know their own strength

Only the best is good enough for whaling ships where complete reliability coupled with strength to resist abrasion by floating ice are of paramount importance. Clyde alloy stainless steel propellers have been meeting these arduous conditions for many years with complete success. Stainless Steel, with its excellent mechanical properties and high resistance to corrosion offers a combination of properties unmatched by other alloys. Our advisory services are at your disposal

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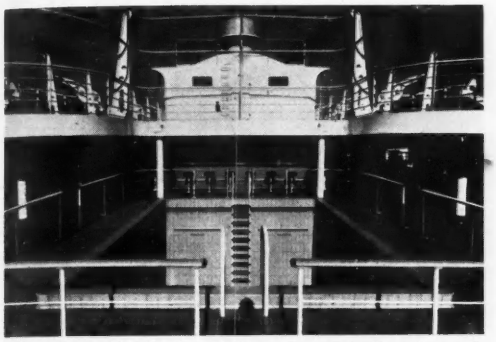
LINER'S LIGHT ALLOY SUPERSTRUCTURE

Trials began on February 24th of a vessel whose whole superstructure above "A" deck, together with funnel, masts, rails and lifeboats, is of aluminium alloy—'MG5' supplied by James Booth & Company Limited, of Birmingham. She is the 21,800 ton "Vera Cruz," built by John Cockerill S.A. of Hoboken, Belgium, and the use of light alloy—which is to Lloyds' requirements—is expected to reduce 'top-hamper' and improve behaviour in heavy seas. The owners, Companhia Colonial de Navigacio, Lisbon, intend to use the "Vera Cruz" to carry passengers and freight to the Atlantic Islands and South America.



View from 'A' Deck of "Vera Cruz," looking forward, showing 'MG5' canopy, rails and engine room skylight.

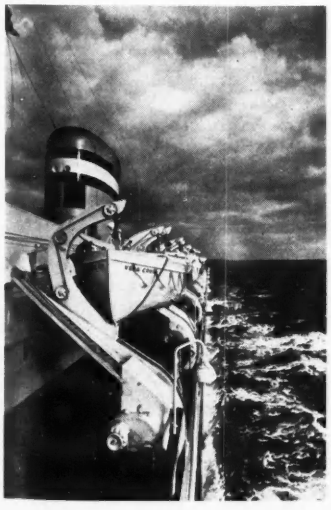
The two topmost decks of the ship are in Booth's 'MG5,' and include the Chart House and Bridge Deck, Officers' Deck, Wheelhouse, Mainmast, Funnel and Engine Room Skylight. The superstructure was built in sections in the shops, assembled by Argon Arc welding and the sections erected on the main structure and to each other by riveting.

Elaborate precautions were taken by Messrs. Cockerill to ensure perfect electrical insulation between the main steel structure and the aluminium superstructure. The cumulative "give" in the riveted joints is counted on to compensate for the difference in the coefficient of expansion between the steel and the aluminium members.

Extrusions and plate alike were delivered primed with a zinc chromate base primer and the fabricators in the shops and the erectors in the ship confirm that the structure needed only touching up at points where processing had removed the primer before painting proper began.

All rivets were in Booth's 'MG5,' and those up to and including ½ in. diameter were driven cold; those greater than ½ in. diameter being driven hot. "Pom-Pom," or percussive type riveters were generally employed.

A sister ship to "Vera Cruz," already in an advanced state of construction in Cockerill's yard, is to be fitted with exactly the same superstructure. Yet a third ship for the same owners is ordered, but not quite so large as the above two. For this, an aluminium superstructure embracing the *three* topmost decks is suggested.



Looking aft. All buildings to the left of the picture and the funnel in 'MG5.' (Lifeboats in aluminium alloys, but Davits supplied by Dutch concern in steel.)

The Sheffield Cutlery Manufacturers' Association announces that it has made arrangements for the initiation of research into cutlery manufacture and for the setting up of a laboratory in Sheffield. The laboratory which will be under the control of the Cutlery Research Council will be located in the British Iron and Steel Research Association's Hoyle Street premises, where B.I.S.R.A. is now building laboratories expected to be amongst the finest of their kind in the world. Initial assistance is being given not only by B.I.S.R.A. but also the Department of Scientific & Industrial Research to the Cutlery Research Council and close collaboration exists between all parties.

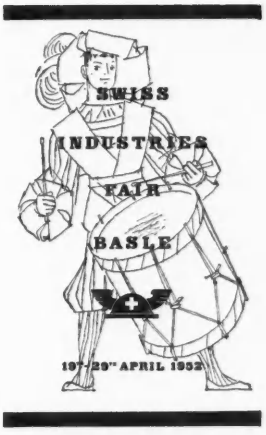
Mr. C. N. Kington, M.B.E., B.Sc., A.M.I.Mech.E., A.M.I.E.E., who is at present employed as Chief Engineer of the British Iron & Steel Research Association Sheffield Group, has been seconded to the Cutlery Research Council as Senior Research Officer, but for the time being will also continue to act for B.I.S.R.A.

Mr. D. A. Palmer, President of the Sheffield Cutlery Manufacturers' Association has been appointed Chairman of the Research Council, Mr. A. S. Milburn, of Richards Brothers & Sons Ltd., Honorary Treasurer, and Mr. E. A. Tuxford, Secretary.

The Mond Nickel Fellowships Committee now invites applications for five Fellowships of average value of £750 each for 1952. Fellowships will be awarded to selected candidates of British Nationality with degree or equivalent qualifications to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British Metallugical Industries. Each Fellowship will cover one full working year. Applicants will be required to state details of the programme they wish to carry out. Particulars and forms of application are available from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms are required by 1st June, 1952.

Northern Ireland is to increase its manufacture of cement, thus relying less on supplies from England. The Minister of Finance (Major J. M. Sinclair) announces that his negotiations with Associated Portland Cement Manufacturers have been successfully concluded, and a new kiln is to be installed at the Company's Magheramorne Works (County Antrim) which, with existing capacity, will provide about 90 per cent. of Northern Ireland's total cement requirements. The new kiln will be installed in about a year.

The Glacier Metal Co. Limited has acquired the capital of Scottish Precision Castings Limited, Hillington Estate, Glasgow, manufacturers of Aluminium and Brass Die Castings.



A warm welcome awaits all trade buyers to this comprehensive survey of Swiss production and progress made within the year.

Full information from the Swiss Legation 18 Montagu Place, London, W.1., or the Swiss Consulate, 53 Spring Gardens, Manchester 2. Details of travel arrangements and currency allowance from any leading Travel Agency or the Swiss State Travel Bureau, 458/9 Strand, Trafalgar Square, London, W.C.2.

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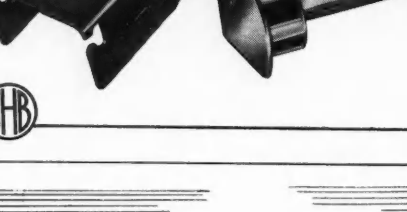

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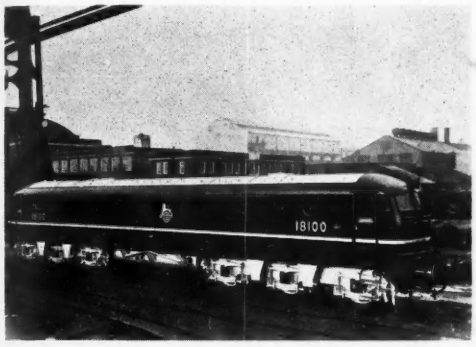
ALUMINIUM ALLOY IN BRITAIN'S FIRST GAS TURBINE LOCOMOTIVE

Extensive use is made of aluminium alloys in the first British-built gas-turbine locomotive, designed and built by Metropolitan-Vickers Electrical Company Limited and recently delivered to the Western Region of British Railways. The cabs at each end, for instance, take the form of separate welded structures in 'MG3' aluminium alloy, and the roof sections between cantrails are of the same material. It is of interest that these are removable for most of the length of the body, for the lifting in and out of equipment. Here the lightness of aluminium alloys has particular application. The same material is used also for the ducts for distributing air to the motors, for the exterior waist-rail, cab entrance door panels, train heating boiler casing, air intake louvres, control cubicle covers, internal doors, driver's desk covers, instrument panels, and certain gas turbine details.



View of complete locomotive

The use of aluminium alloy on this project has enabled motive power equipment of heavier weight than would otherwise have been possible to be accommodated on a locomotive of the Co-Co wheel arrangement. The locomotive is required to haul the heaviest passenger trains on the Western main lines at speeds up to 90 m.p.h. It has a maximum starting tractive effort of 60,000 lbs.

'MG3' is one of a series of alloys manufactured by James Booth & Company Limited, of Birmingham. It was used in this instance as 14 s.w.g. sheet, and in the cab and roof construction as 10 s.w.g., the stiffening members on the roof being usually $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$ extruded angle section, and in the cab structure $2 \times 2 \times \frac{1}{4}$ tee section. The assembly and finish was in general by electric arc welding, but some stiffener sections in the roof were riveted using aluminium alloy rivets.

FIRST SECTION OF SUPER-GRID COMPLETED

The first section of the British Electricity Authority's new 275 kV Super-Grid has just been completed between the new Staythorpe power station and Barnby Moor in Yorkshire. It is the first 275 kV overhead line to be erected in this country and the first to use duplicate conductors. It will reinforce the existing 132 kV national grid system.

The single-circuit line, over 20 miles long, was constructed by British Insulated Callender's Construction Co. Ltd., who had previously designed, supplied and erected an experimental 275/500 kV overhead line at Leatherhead so that the mechanical and electrical problems of overhead transmission at super-voltages could be closely studied. The same firm have constructed over half of the main lines in the present 132 kV grid system.

The completed section of the new system consists of three pairs of standard steel cored aluminium twin conductors and two earth-wires carried on waisted-type galvanised steel lattice towers. The twin conductors, kept 12 inch apart by aluminium spacers and supported by toughened glass insulators, are erected in spans of 1,200 feet. The conductor stringing presented difficulty as equal sags of the twin wires had to be maintained.

The 99 towers in the section—84 straight line, 14 angle and one terminal—are over 80 feet high and were designed by Blaw Knox Ltd.

MICROWAVE WIRING

Details of a new technique, which is designed to replace bulky, expensive waveguide circuits or "plumbing" employed in present microwave systems, were outlined in a series of three papers presented by engineers of Federal Telecommunication Laboratories, Inc., Nutley, New Jersey, research associate of the International Telephone and Telegraph Corporation.

This new advance in the electronic art is based on the use of a ground plane system that acts as a radio mirror for a conductor supported above it, creating, in effect, a parallel wire system in which perfect symmetry is obtained without elaborate machining or other processes.

Chief advantage of the new technique is that is it many times cheaper than the current method of producing microwave circuits. The "jewel-like" machining required in the production of existing components—a major factor in the present high cost of microwave systems—is virtually eliminated.

Under the techniques perfected by F.T.L. engineers, the new wiring can be produced directly from diagrams simply by etching the circuits on a dielectrically coated base plate or by the employment of stamping and embossing techniques. The resulting equipment is not only several hundred times lighter, but a great deal more compact than existing types of microwave plumbing. The magic "T" waveguide, one of the many components employed in present-day microwave systems, weighs approximately 15 pounds as compared with a few ounces under the newly developed printing method. In airplanes, where light, compact equipment is essential, the difference in weight of a radar receiver would be extremely valuable.

The overall advantages offered by the IT & T Laboratories' new method of printing microwave circuits are expected to advance the possibilities of inexpensive television microwave radio relays.

From the military standpoint, it is expected that the new technique will have a far-reaching effect on the design of microwave apparatus.

THE "STANDARD" D.C. MILLIWATT CALIBRATOR

The testing and calibration of thermocouples demands a highly accurate and stable source of low level power. From the viewpoint of accuracy and stability, the obvious basis for such a source is a standard cell, but for testing and calibration purposes a means must be found of obtaining appreciable power for any length of time. This problem has been successfully solved by Standard Telephones and Cables Limited in their 74131-A D.C. Milliwatt Calibrator which uses a Muirhead Miniature Weston Standard Cell Type D-550-A as the reference voltage in a circuit which places no load upon it.

The Standard cell e.m.f. is applied between one of the grids of a double-triode valve and earth, and a voltage derived from a potentiometer network supplied with stabilised D.C. is applied to the other grid. By adjustment of the potentiometer resistance, this voltage can be made equal to the standard cell voltage, and then used as a reference voltage, against which the standard output of 1 mW into either 600 or 75 ohms can be checked.

The Muirhead cell was chosen because it combines a high degree of accuracy and stability with robust mechanical construction and because it is cheap to replace should this be necessary.

CABIN COMFORT FOR TOURIST TRAVELLERS

Passengers flying tourist-class in the 100-seat Bristol *Britannia*, due to go into service in 1954, will travel in pressurized cabins in which the air can be heated, cooled, moistened or dried, as desired.

The latest piece of cabin-atmosphere equipment to be ordered for the turboprop *Britannia* is a humidifying unit, built by the General Electric Company. It consists of an electrically heated boiler controlled by a humidistat—a device which measures the moisture in the surrounding air.

When the relative humidity falls to 25 per cent, the humidistat automatically switches the electric boiler on, and water is fed into the cabin atmosphere as steam. When the humidity rises to over 60 per cent, the humidistat automatically switches the unit off.

BRITISH EUROPEAN AIRWAYS ADOPT DECCA

The Decca Navigator—an automatic airborne navigator—is to be fitted to BEA's fleet of aircraft. It is a radio "brain" which locates the aircraft in the space patterns sent out from ground radio stations. BEA is the first operator to adopt Decca in the air, though it is in use at sea by over 1,000 ships. The Navigator will be used in BEA's entire fleet including the turboprop *Viscounts*, *Ambassadors*, and helicopters.

One version is the Decca Flight Log, which automatically shows the pilot the ground position of his aircraft on a map. A small pointer moves continuously across the map and draws in the track of the aircraft over the ground. The Log works quite independently of atmospheric conditions like wind.

A NEW LIGHTWEIGHT MUD HOG

Pegson Limited (a company of the Mellor Bromley Group) announce the introduction of a new Lightweight Mud Hog, in two sizes, with capacities of 2,000 gallons per hour and 3,200 gallons per hour. This little pump has already proved its worth in America where hundreds are in use for emptying septic tanks and other similar duties. Now in production, the pump will be known as the Pegson Marlow Lightweight Mud Hog. Less than half the weight of other Mud Hogs, the pump is completely portable being easily wheeled by one man or lifted by two men. Small and compact in design it has a welded steel chassis and cushion rubber tyres. Power is supplied by a $1\frac{1}{2}$ h.p. J.A.P. petrol engine with a built in speed reduction gear. The clean out and drain hole is readily accessible and the pump is designed to enable liquids to pass freely under the diaphragm increasing pumping capacity and reducing wear. Other features include: self-aligning crank shaft bearings; strong gear and chain drive with adjustable tension and oil lubrication; completely enclosed chain guard and self cleaning valve seats. The Pump will be featured on the Pegson Stand at the B.I.F. Castle Bromwich.

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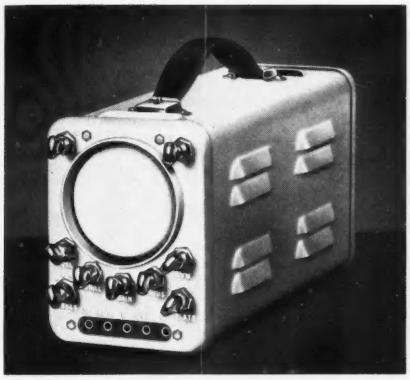
NEW MATERIALS, PROCESSES AND EQUIPMENT

(*Continued from page* 93)

NEW MINIATURE OSCILLOGRAPH

A. C. Cossor Ltd., Cossor House, Highbury Grove, London, N.5, have developed Model 1039, the smallest in the Cossor oscillograph range, a really portable instrument. This new miniature oscillograph, although weighing only 9¼ lbs., is equipped with a 2¾ in. dia. tube, giving a screen size which is quite adequate for most monitoring and servicing displays.



To safeguard against transit fractures, the nine control knobs of the instrument are in metal and the tube face is adequately protected by a domed metallic cap fitting into the raised bezel of the front panel.

Input connections are by five recessed sockets giving access to the X and Y plates, Amplifier, Synchronisation and Earth.

VACUUM PRINTING FRAME

The Miller-Trojan Company Inc. of Troy, Ohio, announces its giant vacuum printing frame for producing photographic metal templates. Used in conjunction with a simple photographic process, it eliminates the laying out of the design on the template by hand. The company states that it definitely reduces costs and increases production. The machine has a counterbalanced top which enables the operator to raise it with hardly any effort. It is equipped with a bank of instant-start, slimline fluorescent tubes which ensure quick, even exposure. One, two, or three circuits with gold, green of black fluorescent tubes are available. Continuous operation is possible without overheating the machine. An automatic timer permits unsupervised exposures from one second to several minutes. The large vacuum pump has three intakes to assure a quick acting vacuum. Heavy gauge, heat-treated glass eliminates breakage problems. The overall printing area of the machine is 68 in. by 144 in. Removable panels permit easy access to tubes and wiring.

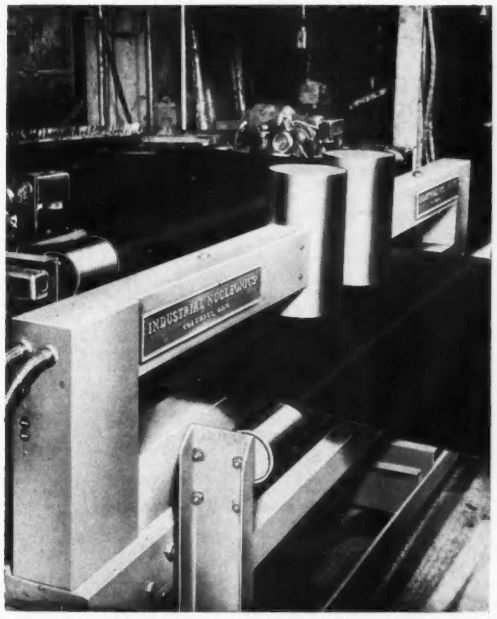
BETA-RAY THICKNESS GAUGE

Designed specifically for continuous measurement of sheet material produced in the rubber, plastic, and paper industries, the AccuRay Beta Gauge, Model R, has been announced by Industrial Nucleonics Corporation, Columbus, Ohio.

New features include an automatic control for positioning the measuring unit across sheet to provide profile readings and a control for the selection of desired weight ranges. Another development is the remote control station with repeat meter which permits the calender operator to read and control the guage from a distant point with an accuracy of $\pm$ 1 per cent.

Of further aid to the operator is the AccuRay recorder which can be equipped with target and tolerance marking pens to provide him with a comprehensive working picture at a glance.

Basically, the gauge consists of a beta radiation source below the sheet to be measured and above it a detector to measure the amount of radiation that penetrates the sheet, plus a recorder to present this information in terms of weight per unit area. The AccuRay is insensitive to temperature variations, line voltage fluctuations, dirt, moisture, shock and vibration.



BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

Scheme of Symbols for Welding. B.S. 499 : 1952 Section 7 contains radical alterations of the former practice. It has been drafted with full knowledge and appreciation of the work to be done in the interests of international collaboration to secure co-ordination between British and American practices. It is part of a wide scheme of co-ordination which will include drawing office practice, Unification of screw threads and other matters discussed at the Ottawa Conference on Unification of engineering standards in 1945.

It departs from previous practice in two fundamental respects. The terms " near side " and " far side " have been discontinued in favour of the terms " arrow side " and " other side." This not only provides uniformity with the American scheme, but overcomes the difficulty encountered in some views of welds where the former terms were inapplicable. It has also been decided that the disposition of the weld symbol relative to the reference line should be based on the American system. At the outset, this might appear to be a reversal of former practice, inasmuch as the symbol is placed below the reference line for welds on the " arrow side," instead of, as formerly, above the reference line for welds on the " near side," but this reversal is true only to a limited extent. Nevertheless, many of the features of the former scheme have been preserved. Price 6/-.

Oxy-AcetyleneWelding of High Temperature and High Pressure Pipelines. B.S. 1821 : 1952 is the first of a series being prepared for the welding of pipelines and covers pipelines for service conditions in which the pressure exceeds 250 lb./sq. in. and/or the temperature exceeds 425° F (220° C).

The standard lays down the conditions for shop and site welding of joints in such steel pipelines and fittings up to and including 20 in. diameter, and is divided into four parts.

Part 1 defines the parent metals and specifies the types of filler rods, welding technique, general precautions and qualifying tests for welders.

Part 2 deals with butt joints and specifies the method of preparation and requirements for the completed welds. This section covers not only plain butt welds but also flanges and bends, both gusseted and cut-and-shut.

Part 3, for branches, includes details of preparations for the set-on and set-in types.

Sleeve welds are covered in Part 4.

The standard is amply illustrated by line diagrams and by photographs of satisfactory and unsatisfactory welds. Price 6/-.

Length Bars and Accessories. B.S. 1790 : 1952 relates to length gauges of the cylindrical bar type in both inch and metric units, and standards of accuracy are specified for reference, inspection and work-shop grades. In addition, the essential features of design and accuracy are specified for the two types of accessories commonly used with work-shop bars, namely : those for use with collet attachments and those for use with screws and studs. Recommended sets of work-shop bars are given in an appendix. Price 3/-.

Nickel Clad Steel Plate. B.S. 1822 : 1952 specifies steel plate to which a layer of nickel is integrally and continuously bonded on one or both sides.

The base steel is required to comply with B.S. 1501 -151, -154, or -157. A high purity nickel is specified and tests are included to ensure efficient bonding between the nickel and the steel. Price 2/-.

Aluminium and Aluminium Alloy Sections. P.D. 1331 is intended to give guidance to the prospective user, who may be unfamiliar with the characteristics of the different aluminium alloys available in the form of extruded sections. These notes recommend that in choosing an alloy for a particular purpose consideration be given not only to the mechanical and structural strength of the material but also to the ease with which it may be formed and then incorporated into a structure, and its durability under conditions or service. Notes on the working and heat treatment of the various alloys and Tables of torsion constants for the sections specified in B.S. 1161 are included. Obtainable free of charge.

Welded Steel Boilers for Hot Water Central Heating and Hot Water Supply. B.S. 855 : 1952 applies primarily to hot water central heating and hot water supply welded steel boilers of over 5 sq. ft. heating surface for operation on systems vented to atmosphere and operating at pressures not exceeding 150 ft. head (65 lb/sq. in.) and at temperatures not exceeding 212° F., i.e. gravity or accelerated systems.

Part 1 deals with fuels, rating, heating surface, firegrates, dampers and doors (assembly of boiler), ashpit, boiler openings, inspection and cleaning holes, provision for emptying, marking and materials.

Part 2 describes the method of testing boilers for the determination of the water heating efficiency at rating. It also includes an overload test. While the testing of boilers is not obligatory under the terms of Part 1 of this standard, British Standard boilers should be capable of giving their rated output under the condition of the Test Code, Sections One, Two and Three, and of satisfying the requirements of the Test Code Two.

The revised standard contains more stringent requirements for the control of air entering the ashpit damper, the damper is required both to fit more closely so that when it is closed there is little, if any, air leakage, and to be so made that the small amount of air required under banking conditions can be controlled accurately. Price 6/-.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

TECHNICAL ENGINEER ASSISTANTS and Draughtsmen required by a Lincoln firm. Exceptional opportunity for engineers with initiative, experience in design of automobile components an advantage. Please write giving full particulars to Box No. C.D.18, " The Engineers' Digest."

ROBERT DEMPSTER & SONS, LTD., Elland, Yorkshire, require Senior Estimating Draughtsmen in their Mechanical Handling Project Department with experience in the design and estimating of Mechanical Handling Plants for Power Stations and Gas Works. Voluntary Superannuation Scheme. Applications to the above address, endorsed " M.H. Project Department," stating age, details of experience and salary expected. J345.

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